Volum JANUARY 1931 Number 1

BULLETIN
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The subscription price to non-members of the Association is $15.00 per year (separate numbers $1.50) prepaid to addresses in the United States. For addresses outside the United States, an additional charge of $0.40 is made on each subscription to cover extra wrapping and handling.

British agent: Thomas Murby & Co., 1 Fleet Lane, Ludgate Circus, London, E. C. 4.

German agent: Max Weg, Königstrasse 3, Leipzig, Germany.

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J. P. D. HULL, *Business Manager*
THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.
BOX 1852
TULSA, OKLAHOMA

Entered as second-class matter at the Post Office of Tulsa, Okla., under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

MID-WEST PRINTING CO., TULSA, OKLA., U. S. A.

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BULLETIN

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JANUARY 1931

GEOLOGY OF OIL FIELDS OF POLISH CARPATHIAN MOUNTAINS[1]

HENRY DE CIZANCOURT[2]
Paris, France

ABSTRACT

The Polish Carpathian oil fields are located in the formations of the Flysch facies, ranging in age from Lower Cretaceous to lower Miocene.

Oil is concentrated in two distinct tectonic zones. (1) In the Marginal zone—particularly in the deepest element of that zone—directly overthrust onto the fore-land, are the large fields of Boryslaw-Tustanowice-Mraznica, Rypne, and Bitkow. On that deep element is overthrown a folded and faulted mass which contains oil, as at Schodnica. The width of the overthrust exceeds 7 miles. (2) In the Central depression—more particularly in the vicinity of Krosno—many fields, generally of minor importance, are related to anticlines; for example, Wankowa, Krosno, Rowne-Rogi, Harklowa, and Lipinki. The main oil horizons are Eocene and Oligocene in age.

Because of the overthrusts, the problem of the origin and of the migration of oil in the Carpathians is particularly difficult to solve. The main fields of the Marginal zone correspond with the uplifts of the substratum, but they do not coincide everywhere with the uplifts of the overthrusts; hence, there is some discrepancy between the surface structure and the location of the oil fields.

INTRODUCTION

The relative economic importance of the oil fields of the Polish Carpathian Mountains is not very great; however, because of the complexity of their geological structure, the fields are of interest to the geologist.

In this paper the writer attempts to show the most characteristic features of the Polish Carpathian Mountains, according to the most

[1]Read by title before the Association at the Fort Worth meeting, March 23, 1929. Manuscript received June 6, 1930.

[2]Compagnie Française des Pétroles, 63 Avenue Victor Emmanuel, III, Paris. Formerly chief geologist, Premier Oil Company, Poland.

recent work of Jan Nowak, W. Rogala, W. Teisseyre, K. Tolwinski, R. Zuber, and the recent publications of the Carpathian Geological Station of the Polish Geological Survey (B. Bujalski, H. Goblot, L. Horwitz, E. Jablonski, St. Krajewski, Z. Opolski, B. Swiderski, St. Weigner, H. and M. de Cizancourt, and others). The writer indicates the character of the principal oil fields, partly according to the studies being published by the Carpathian Geological Station, partly according to his own notes. Further, he tries to show the factors which had an influence upon the localization of the oil fields known at present, and to discuss the principal theories which have been formed thus far.

This paper had been written when Nowak's work on the same subject, *The Geology of the Polish Oil Fields*,[1] became available, but the writer did not think it necessary to modify his text, as the general part of Nowak's study repeats almost exactly Nowak's previous work. It may be noticed that some fields are described somewhat differently, by use of the most recent documents which were in the writer's possession. Moreover, as the divergencies of view are merely those of details, it does not seem necessary to depart from the plan of this paper to discuss them. However, in the sections on localization of the oil fields and origin of the oil, the writer indicates and discusses Nowak's most recent conceptions.

At the end of this paper is a summary of the geological literature of the Carpathian Mountains, including only the principal general publications and omitting the studies of details.

It is a pleasure to make acknowledgment to the writer's Polish colleagues, particularly Bujalski, Jablonski, Krajewski, Swiderski, Tolwinski, and Weigner, for their kind welcome during his stay of six years in Poland, and for all the courtesies and discussions by which he has greatly profited.

GENERAL REMARKS

The Carpathian Mountains, as a whole, constitute the eastern prolongation of the Alps. There are recognized an Interior crystalline and Mesozoic zone, and an Exterior zone of the Flysch facies, in which are concentrated all the Polish oil fields. The Exterior zone rests on a Miocene foreland.

1. The Interior zone comprises the Tatra and the Pieniny mountains. The Tatra Mountains consist of a crystalline and a Mesozoic series ending at Gault, and the Pieniny Mountains of a Mesozoic series.

[1] Jan Nowak, *Die Geologie der polnischen Ölfelder* (Ferdinand Enke, Stuttgart, 1929).

This mass was folded in Cenomanian time. The Eocene, which transgresses the folds thus formed, was little disturbed by the subsequent Tertiary folding. On the whole, during Tertiary folding, this zone acted like a rigid mass, which only in the course of considerable time could undergo readjustments of detail.

2. In front of the Interior zone, and separated from it by an abnormal tectonic contact, is the Flysch zone, formed of terrains ranging in age from the Lower Cretaceous to the Oligocene. These formations are developed in the Flysch facies. The breadth of this zone ranges from 70-80 kilometers (43-50 miles) in the central and western parts to 30 kilometers (19 miles) at the south end in Bukowina.

Structurally, the region may be divided into two mountainous zones separated by a longitudinal depression. The first, or Interior, mountainous zone corresponds with a tectonic zone characterized by a special facies; this is the Magura zone, which represents, at least in the western part of the chain, the Beskide zone of Uhlig. All of the second mountainous zone, which constitutes the border of the Carpathian Mountains, and the Central depression, form the Central zone of Nowak.

On the border of the Central zone appears, as indicated by certain elevations, a third tectonic element: the deep, or Marginal Eastern element.

The relations of these several elements are as follows. The Magura zone is overthrust onto the Central zone, the Central zone onto the Marginal zone, and the Marginal zone onto the foreland.

3. Finally, the foreland is formed by a folded Miocene series which on its northern border rests unconformably on the old formations, Paleozoic and Mesozoic, of the Sudety, of the Mountains of the Holy Cross, and of Podolia.

STRATIGRAPHY

As the stratigraphy of the Flysch zone as a whole is uniform, these three zones, formerly separated, are considered together.

The beginning of the Flysch facies, in the region where later the Carpathian Mountains were formed, dates from the Lower Cretaceous. The rocks which form their substratum are to-day hidden by the folds of the Flysch. These rocks contain a complete series ranging from the crystalline to the Tithonian.

The scarcity of fossils in the Flysch for a long time hindered the establishment of a precise stratigraphy, and even to-day, although there has been much progress, the stratigraphical divisions are based chiefly upon the petrographic character of the series.

1. *Cretaceous.*—The Cretaceous is the base of the Flysch series, and it crops out in the cores of the anticlines and at the base of the overthrusts.

The lowest formations of the Cretaceous are known only in Silesia, in the western part of the Polish Carpathian Mountains, where, in some places, they contain a fauna by which their age is established with precision. These are the Cieszyn formations, whose base corresponds with the transition of the Jurassic into the Cretaceous, and whose top represents the Valangian: black or dark gray bituminous shales, in the middle of which is a prominent limestone horizon. This series is at least 800 meters (2,624 feet) in thickness.

Above is the Grodischt sandstone, a prominent sandstone horizon which represents the Hauterivian.

The Wernsdorf or Spas shales are of considerable extent. They are known in the Western Carpathians and in many places in the Eastern Carpathians, and in the same group are the Audia shales in Roumania. These beds are black shales commonly containing layers of hornstone and of sphero-siderite. Their age is Barremian or Aptian.

The Ellgoth formation and the sandstone of Godula occur higher in the section, ranging in thickness from 800 to 900 meters (2,624 to 2,952 feet). They represent the Albian and are limited to the western part of the chain. In the northwestern part they are represented in some places by a gap, which causes the Upper Cretaceous to lie directly upon the Aptian or the Barremian. In the southeastern part this gap is not found, and there seems to have been a continuous deposition of the Wernsdorf shales upon the *Inoceramus* formation, both later formations.

In the Upper Cretaceous there is a clear differentiation of the facies. In the western part, it is represented by the facies of black shales with intercalations of sandstones and conglomerates, or Silesian facies of Istebna; in the eastern part, it is represented by the *Inoceramus* formation of light gray shales and calcareous sandstones very poor in fossils. This formation is well represented in the Eastern Carpathian Mountains. In the marginal region it is overlain by massive sandstone, or Jamna sandstone, which represents the upper part of the Cretaceous, and the thickness of which ranges from 40 to 100 meters (131 to 328 feet). It does not exist in other places.

2. *Eocene.*—The Eocene is represented by the Hieroglyphic formation and forms a characteristic group. Three divisions may be made: at the bottom, red and green shales and siliceous sandstones; in the middle, a sandstone layer; and at the top, green shales and sandstones.

FIG. 1.—Siliceous limestone and red shales of Lower Cretaceous.

In detail, however, many variations are observed. The sandstone series in places disappears, or where it is well developed, it is known as the Wygoda sandstone, or locally as the Pasieczna limestone in the Eastern Carpathian Mountains, and as the Ciezkowice sandstone in the Western Carpathian Mountains.

The upper division occurs in the Eastern Carpathian Mountains as a special facies of sandy shales with exotic blocks, known as the Popiele shales.

3. *Menilitic shales.*—This is one of the most characteristic formations of the Carpathian Mountains. It consists of bituminous black or brown shales, finely bedded, with fish remains (Meletta). At the base is a hornstone horizon. Sandstone intercalations in the series are important in some places.

FIG. 2.—Pasieczna limestone and lower Eocene shales in the Bystrzyca Valley.

This formation, which is well developed in the Marginal and Central Carpathian Mountains, is almost unknown in the Magura zone, and this is one of the clearest features of the facies. The age of the Menilitic shales generally has been considered as Lower Oligocene, but recent studies[1] based on *Foraminifera* connect them with the middle-upper Eocene. The formation corresponds with a period of rest and the filling of the sedimentation area. Its thickness ranges from 150 to 400 meters (492 to 1,312 feet).

4. *Oligocene.*—The Oligocene is represented by an important deposit of shales and sandstones, known as the Polanica formation in the marginal part and the Krosno formation in the central part; and by a more sandy and conglomeratic facies, the Magura sandstone, the most characteristic horizon of the Magura zone. Deposition in the Magura and Central zones ended with this formation, which may prove to be very thick.

5. *Miocene.*—In the Exterior or deep element, deposition continued with the beginning of a different facies, consisting of plastic clay

[1]Mary de Cizancourt, "Sur quelques nummulites du Flysch karpatique," *Kosmos* (Lwow, 1928).

FIG. 3.—Crest of Oligocene sandstones and small glacial lake in Czerna Hora Mountains.

with salt and gypsum. Deposition in the Carpathian Mountains ended with the Saliferous clay.

A special tectonic element binds the Carpathian Mountains with their foreland, namely, the zone of Sloboda Rungurska, developed in the southeastern part of the Polish Carpathian Mountains and in the Roumanian Carpathian Mountains. This zone is characterized by the following stratigraphical series.

A large mass of conglomerates composed of material from the substratum of the Flysch formation, for example, Paleozoic phyllites, and Triassic and Jurassic limestones, which probably has a thickness of several hundred meters, lies on the Menilitic shales, either directly, or with an intercalation of Saliferous clay. Their contact with the underlying series is probably an unconformity, but the subsequent tectonic movements have disturbed them and made observation of them difficult. The age of the conglomerates, known as Burdigalian in Roumania, is not determined in Poland. Above are the Dobrotow formation, representing calmer deposition of shales and sandstones; the red shales; and the Saliferous clays.

FIG. 4.—Conglomerates of Sloboda Rungurska (*S*) and Dobrotow formation (*D*) at Nadworna.

At the outer border of this zone is the foreland, which contains a Miocene series, Helvetian-Tortonian, beginning with an important series of Saliferous clays with salt and potash deposits, overlain by the series of pink marls, the sandy Balicze formation, and the Cerithium formation, or fossiliferous Tortonian. Finally, the Tortonian is overlain locally by the Sarmatian in the regions farther from the border of the Carpathian Mountains.

Altogether, the Carpathian Flysch is characterized by the rhythmical alternation of shales and sandstones repeated to make a thickness of more than 2,000 meters (6,560 feet). This was diastrophic deposition in connection with unceasing orogenic movements. Its material came from far, as is shown by the distribution of the conglomerates, and it was supplied by a series of islands extending northwest and southeast. Nowak[1] attempted recently to reconstruct their location and relation.

The establishment of the Flysch facies began in the Lower Cretaceous, but was soon afterward interrupted in the Western Carpathian

[1]Jan Nowak, *Zarys tektoniki Polski* (Krakow, 1927). (Polish.)

Mountains by the emergence subsequent to the Tatra tectonic movements, although in the Eastern Carpathian Mountains deposition does not seem to have been disturbed by these movements.

With the return of the sea in the Upper Cretaceous, the previously emerged zone received the deposit of the Silesian facies—facies of elevation—while farther east the *Inoceramus* formation—facies of depression—was deposited.

A series of small secondary movements is represented by sandstones or conglomeratic beds such as the Jamna sandstone in the Upper Cretaceous and the Wygoda-Ciezkowice sandstone in the Eocene. The Menilitic shales, on the contrary, correspond with a period of rest. However, the changes began again in the Oligocene, and culminated at the end of that period in the emergence of the Magura and Central zones.

The deep element was being folded after the deposition of the Saliferous clay, while the Exterior zone was still receiving the deposition of the Sloboda series.

Finally, the formation of overthrusts and the definite emergence of the Carpathian Mountains occurred in the Tortonian. This is explained by the deposit of pronounced Tortonian conglomerates with Carpathian boulders.

TECTONICS

The beginning of the Flysch facies in the Lower Cretaceous caused a radical change in the character of the deposits; therefore, there is no reason to be surprised if it is found that the Flysch cover and its substratum were affected in different ways by the orogenic forces.

Overthrusting by the Flysch, and its folding independent of its substratum, form the principal tectonic characteristic of the Carpathian Mountain Flysch. The substratum must have been folded likewise, but its folds are not exposed to observation; only in the extreme south part of the Polish Carpathians does such a fold crop out.

As stated at the beginning of this paper, three great tectonic units are recognized in the Flysch of the Carpathian Mountains: the Magura, the Central, and the Deep Marginal zones.

1. *Magura zone.*—This zone corresponds with the western part of the Beskide zone of Uhlig.[1] It forms an arch concentric with the Pieniny arch, and is characterized by special facies, particularly by the absence of the Menilitic shales and by the development of the Magura sandstone in the Oligocene. This unit is much folded, and is composed of several

[1] V. Uhlig, "Über die Tektonik der Karpathen," *Sitzungsb. d. Akad. d. Wissensch.* (Wien, 1907).

secondary units. On its northern border it is thrust onto the Central element, and the amplitude of the thrusts indicated by the presence of the outliers and the inliers attains 15 kilometers (9 miles) in the region between Harklowa and Jaslo. With the exception of tectonic inliers in connection with the Central zone, this unit is not oil-bearing.

2. *Central zone.*—Two tectonic regions form the Central zone. In its western part is the Central depression folded in anticlines more or less faulted; in the east is part of the Carpathian Mountains of the border, which are thrust onto the Marginal zone, and which are cut into a series of secondary thrusts, continuing through long distances with great regularity, and with only small divergence from the axis.

At the center, these folds are generally composed of the Cretaceous. They are separated by synclines of the Polanica or Krosno formation. In the exterior elements, at the base of the thrusts, is the *Inoceramus* formation. In the Carpathian Mountains of Skole, however, fragments of the Barremian-Aptian occur at the base. Most of these folds rise longitudinally from a plunging anticline which, toward the northwest, grades into a faulted fold meeting the Carpathian border at an oblique angle, and disappears toward the west (Fig. 5).

Several groups of folds are recognized.

In the eastern part, the border of the Carpathian Mountains is formed by a marginal, little developed faulted fold, which has at its base only fragments of the Cretaceous and in some places wholly lacks Cretaceous. This group is in places completely separated from the next group, as at Boryslaw; in places they are united by a synclinal trough more or less broken.

A second group of folds is formed by the folds of Orow, which constitute the border of the Carpathian Mountains south of Delatyn. Only Cretaceous masses appear in the zones of elevation; in the zones of depression these masses are reduced into a series of folds separated by Eocene or Oligocene synclines. The syncline of the hinterland of this group is well developed and is broken by a productive anticline at Schodnica.

On this syncline is a series of folds, or the Skole overthrust, characterized by the presence of the complete Cretaceous with the Barremian-Aptian at the base. This group is composed of a series of four or five folds, which toward the south grade into regular anticlines.

Finally, the folds sink more and more, and form the Central depression in which is the Krosno formation. This depression acts as the hinterland in comparison with the ensemble of the preceding frontal

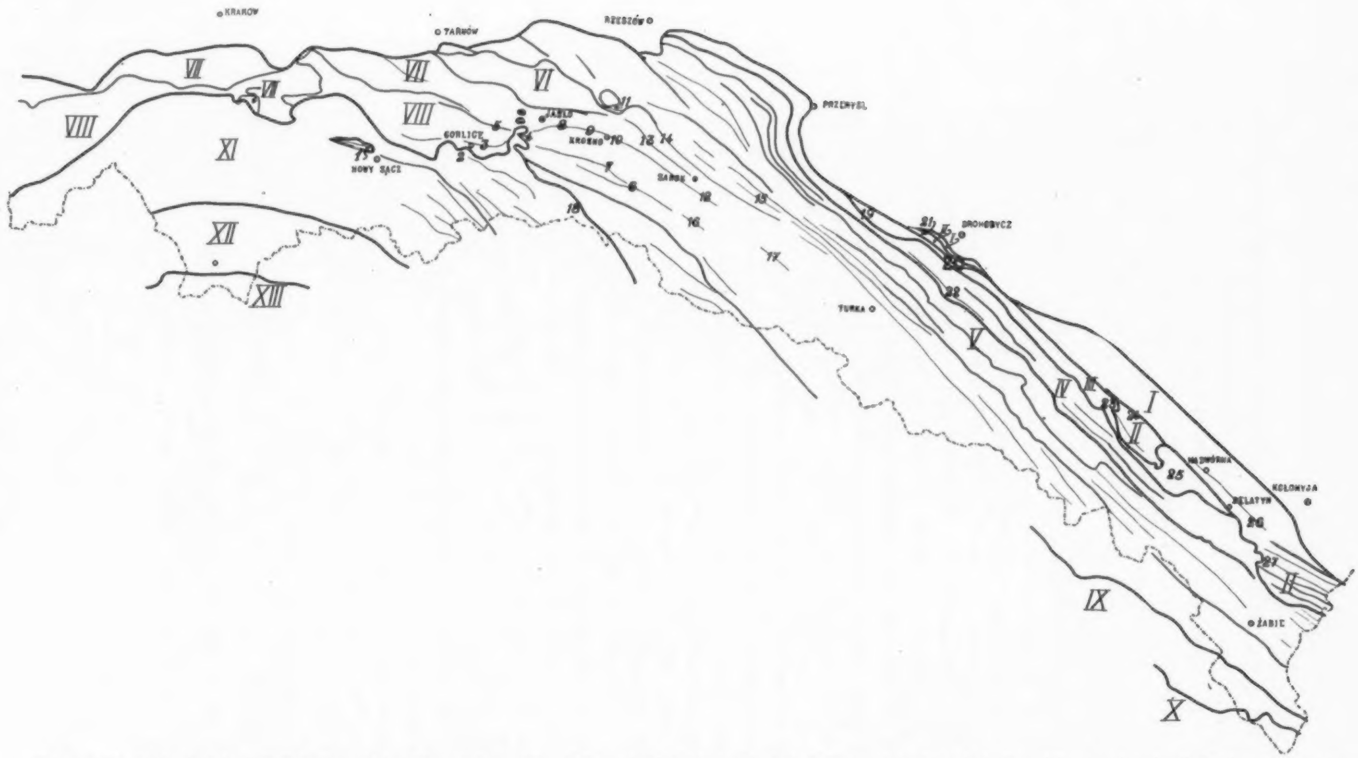

FIG. 5.—Tectonic sketch of Polish Carpathian Mountains. After J. Nowak, K. Tolwinski, *et al.*, "Carte géologique de la Republique polonaise." Scale, 1:2,400,000. Length of area mapped, west (left) to east (right), approximately 198 miles. Legend: I, Sloboda Rungurska zone; II, Deep Marginal element; III-VIII, Central zone (III, Marginal fold; IV, Orow folds; V, Skole folds; VI, Chelm-Czarnorzeki fold; VII, Liwocz fold; VIII, Wisnicz fold); IX-X, Pietros and Bukowina overthrusts; XI, Magura zone; XII-XIII, Pieniny and Tatra zones.

Oil fields: 1, Kleczany; 2, Ropica Ruska, Sekowa; 3, Kryg, Kobylanka, Libusza, Lipinki, Pagorzyna; 4, Harklowa; 5, Biecz; 6, Wulka Lubatowka; 7, Bobrka, Rowne, Rogi; 8, Gas fold (Bialkowka, Dobrucowa, Mecinka); 9, Krosno-Potok; 10, Krosno-Kroscienko; 11, Weglowka; 12, Zagorz-Wielopole; 13, Zmiennica-Turzepole; 14, Grabownica, Humniska, Starawies; 15, Wankowa, Ropienka, Paszowa, Lodyna; 16, Mokre; 17, Polana; 18, Ropianka; 19, Strzelbice; 20, Boryslaw-Tustanowice-Mraznica; 21, Nahujowice; 22, Schodnica, Urycz, Pereprostyna; 23, Rypne; 24, Majdan, Rosulna; 25, Bitkow-Pasieczna; 26. Sloboda Rungurska; 27, Kosmacz.

overthrusts. The depression continues with great regularity from the Bukowina as far as the Western Carpathian Mountains.

However, beginning with the Sanok region, several folds, which outside this area form only narrow anticlines, rise abruptly and become thrust folds, which extend to the border of the Carpathian Mountains. It is not necessary to indicate in this paper the details of these folds (Fig. 5, *VI-VIII*).

In the Eastern Carpathian Mountains a second elevation causes a series of tectonic units to emerge from the depression described by Nowak[1] and Swiderski[2] as the Czernahora overthrust, or the Pietros overthrust, next the crystalline core of this last unit, which was formerly considered equivalent to the crystalline massif of the Tatra Mountains, but which has recently been shown by Nowak[3] to have emerged from the depression. This fact is interesting, because this is the only place in the Polish Carpathian Mountains where the substratum crops out.

3. *Deep or Eastern Marginal zone.*—The Central zone rests on a unit which is characterized by the presence of the Saliferous clay at the top of the stratigraphical series. Generally this unit is hidden by the thrust of the Central zone and appears only in the zones of elevation: as the inlier of Maniawa and Pokucie; it has been found by drilling under the thrust of the Central zone. The extent of the overthrust is 4 kilometers (2½ miles), as proved by drilling at Boryslaw, and 10 kilometers (6 miles) proved by drilling and by the presence of tectonic inliers in the region of Bitkow-Maniawa.

This unit continues from the Roumanian border as far as Boryslaw. At Boryslaw it has the aspect of a fold almost horizontally recumbent on the saliferous Miocene of the foreland. This unit is found with the same complications in the Maniawa inlier, formed by two principal anticlines accompanied by secondary anticlines. Traces of it are lost east of Bitkow, but in the Pokucie region is a system of seemingly related folds.

The exterior anticlines of the Pokucie region are covered with a particular Miocene series, the Sloboda series previously mentioned. The tectonic interpretation of this region is still under discussion; mean-

[1] Jan Nowak, *Les unites tectoniques des Carpathes polonaise orientales* (Lwow, 1914).

[2] B. Swiderski, "Geological Structures of the Pokucie Carpathian," *Station geol. karp. Bull.* 7 (1925).

[3] Jan Nowak, "Nouvelles données sur l'ensemble de la tectonique des Carpathes," *Mem. Association Karpatique* (Lwow, 1927).
Idem, Zarys tektoniki Polski (Krakow, 1927).

while, it is known that this Sloboda series detached from its substratum has moved forward to the foreland, of which it constitutes the part nearest the Carpathian Mountains.

4. *Autochtone.*—The foreland proper, outside of the Sloboda zone which forms a part of it geographically, consists of a Helvetian-Tortonian folded series, lying unconformably, at the north, on the old formations.

The previously mentioned anticlines or overthrusts are the result of axial undulations.

On the whole, there is recognized (1) an elevation of the Western Carpathian Mountains, west of a line from Sanok to Przemysl, characterized by the existence of a gap in the Cretaceous and by the development of the Upper Cretaceous in the Silesian facies; (2) a depression in the medial region with secondary culminations at Boryslaw and at Majdan; and (3) an elevation of the Eastern Carpathian Mountains, characterized by the appearance of the folds of Pokucie, and by the exposure of the crystalline formations at Marmarosh.

The folds of the Flysch zone have been developed tectonically independent of the substratum, but the latter may have had some influence upon their movement.

Teisseyre[1] thus tried to show that the great dislocations of the foreland continue in the Carpathian Mountains, but, on the whole, this influence is small and the folds move from the zones of elevation to those of depression without obviously modifying their direction.

Although it can not be denied that the substratum has an influence, the Flysch folds do not reflect the dislocations of the substratum; instead, they reflect the irregularities of the topographic surface of the substratum, which have hindered the progress of the folds of the over-riding Flysch and have caused tectonic complications in some places: contraction of the folds into virgations[2] accompanied by secondary dislocations, as faults. This problem will be referred to later in presenting concrete examples.

POLISH OIL FIELDS

HISTORICAL SKETCH

For a long time the many seepages of oil in the Carpathian Mountains have attracted the attention of the inhabitants, who have developed

[1] W. Teisseyre, "La tectonique comparée des Subcarpathes," *Kosmos* (Lwow, 1921).

[2] Virgation: branching, like twigs from a bough.

them for their own needs. These phenomena were mentioned by the early writers in their travel records.

Sloboda Rungurska was mentioned as early as 1771; according to Hacquet, in 1791, there was produced at Nahujowice 43 barrels yearly and it was the largest production of the country at that time; in 1797 the canon Christopher Kluk mentioned Ropienka; and in 1815 the Polish geographer Staszic mentioned Nahujowice. From the beginning of the 19th century Boryslaw, also, has been known because of its seepages and its wax pits, the latter serving for the manufacture of candles.

Meantime, a pharmacist from Lwow, Ignacy Lukasiewicz, was the first to realize the importance of oil for lighting purposes, and, by systematic work, he tried to obtain petroleum in larger quantities. He commenced his research in 1854 in the Krosno region, and undertook the digging of wells by hand in the Bobrka region. After a difficult beginning, in 1861 he encountered oil at a depth of 14 meters (46 feet) and produced 6,000 kilograms (6½ tons) per day. Subsequently this field became one of the best in the Western Carpathian Mountains. At about the same time, in 1856, the development of the Boryslaw seepages was begun; similar work had been undertaken at Kleczany in 1858.

The first considerable progress was in 1863, when introduction of the drilling bit made deeper drilling possible. The system used at that time consisted of digging a pit by hand down to 20 or 30 meters (65-98 feet), at which depth drilling was continued by means of a very simple hand derrick. The depth attained was not more than a few hundred meters.

Since that time, several fields have been developed in the Western Carpathian Mountains: Kleczany, Bobrka, Lipinki, Ropianka, Ropica Ruska, Siary, Plowce, Kroscienko, and others. The first important field in the Eastern Carpathian Mountains, Sloboda Rungurska, was discovered by Szczepanowski in 1881.

From 1881 to 1900, much drilling resulted in the discovery of most of the fields developed to-day. The name of McGarvey is specially connected with the western fields; the name of Szczepanowski, with the development of the fields of the Eastern Carpathian Mountains. One of the most important fields was Schodnica, discovered in 1890, which reached its maximum in 1896.

At that time the Boryslaw field, by far the most important in Poland, was discovered. There also oil had been known for a long time; in 1856 natural seepages were worked by hand-dug pits, but after 1862 the production of oil became of secondary importance as compared

with the production of wax. Subsequent to 1866 more than 4,300 pits were dug close together on a space of 100 hectares (247 acres), some of them more than 100 meters (328 feet) in depth. Since 1890 more rational methods of development by means of wells and galleries have been introduced and there exists yet an active wax mine.

The first serious search for oil by means of drilling was made by McGarvey, who, in 1895, found the first commercial production at a depth of 600-800 meters (1,968-2,624 feet). Since that time, the eastern part of the field (Potok) has been drilled, and in 1902 the first well at Tustanowice (western part) was drilled, so that 300 tons per day were being produced in 1903. In 1909 the maximum production of the field was attained, representing 93 per cent of the whole production in Poland.

After the war and reconstruction period, when the wells that had been dismantled or burned were reclaimed, it became necessary to modernize drilling methods because of the great depths reached in present development: 1,500-1,800 meters (4,920-5,904 feet). The American drilling systems, rotary and cable, were introduced by the Premier Oil Company. The cable system, especially, has given good results, and is generally used to-day.

The necessity of finding new fields in order to replace the loss in the Boryslaw production, which was only partly counterbalanced by the development at the south (Mraznica), caused the resumption of drilling in other fields as well as wildcatting. Thus were developed the fields of Rypne, Bitkow, and Majdan in the Eastern, and those of Biecz, Krosno (gas), and others in the Western Carpathian Mountains, where fields now abandoned formerly existed. At the same time the important gas field of Daszawa was discovered in the foreland.

GEOLOGY

The oil fields in the Polish Carpathian Mountains may be grouped in two zones: the Central depression and the Carpathian Mountains of the border. As these zones are very different, tectonically, the oil fields are also different.

Oil fields of Central depression.—The oil fields of the Central depression are concentrated in the Krosno and Gorlice regions, that is, in its western part. This zone corresponds with an area of relative elevation.

As the short anticlinal folds of this zone, with generally abrupt flanks, did not favor a large concentration of oil, there is accumulation at many different places developed by numerous tests of secondary importance. The production table shows many fields now developed

and if the abandoned fields are added, together with the points where exploration has proved oil to exist but not in commercial quantities, the number would be larger.

From the west, the first group of oil fields found in the Nowy Sacz region is Kleczany, to-day almost abandoned, but interesting because of its position in the Magura zone. The production of this field, however, is not obtained from the Magura zone, but from the Krosno formation of the depression occurring in a tectonic inlier under the Magura zone. The wells are shallow, 150-200 meters (492-656 feet), but the oil is remarkable because its vaseline content reaches 40 per cent.

Under analogous conditions many seepages occur in the same region, but no more oil in paying quantities has been found.

At a distance of 30 kilometers (18½ miles) farther, a second well characterized group includes the fields of the Gorlice region. Immediately south of Gorlice there are the old fields, to-day almost abandoned, Ropica Ruska, Mecina, Siary, Szymbark, and Sekowa, located on the front of the Magura overthrust and producing oil from the autochtonous Krosno formation of the depression, or of the overthrust *Inoceramus* series.

In the north is developed the autochtonous zone broken by a large anticline where the Eocene occurs. This anticline divides into two secondary anticlines on which are several small fields: Kryg, Kobylanka, Dominikowice, Lubusza, Lipinki, Wojtowa, and Pagorzyna, the most important of which is Lipinki, which has been producing nearly 58 years. These fields are producing from the Eocene sandstone of Ciezkowice and are characterized by small but remarkably constant production. The wells are not very deep, the deepest horizon being at 800 meters (2,624 feet).

Toward the east, the fold, which has extended eastward as far as Lipinki, turns abruptly north, and the front of the Magura overthrust follows the same course, forming the outlier of Harklowa. The Harklowa field is classed in the second rank of the producing fields in the Krosno region. The structure[1] of this field is very complicated. Oil is produced from the Krosno formation in a dislocated anticline located under the outlier of the Magura overthrust. It is not known whether this anticline is the extension of that of Lipinki-Wojtowa, or whether it represents a more northern fold.

A little farther north, the Biecz field is on an anticline plunging toward the east. This field, like that of Lipinki-Wojtowa,

[1]H. de Cizancourt. "Harklowa" in "Gisements de pétrole en Pologne," *Station géol. karp. Bull. 15* (1927).

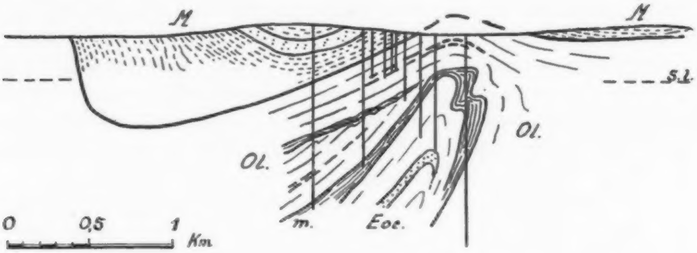

FIG. 6.—Southwest-northeast cross section of Harklowa field. *Eoc*, Eocene; *m*, Menilitic shales; *Ol*, Oligocene; *M*, overthrust Cretaceous and Eocene of Magura overthrust; *s. l.*, sea-level. After H. de Cizancourt, "Harklowa," in "Gisements de pétrole en Pologne," *Station géol. karp. Bull. 15* (1927).

FIG. 7.—Pumping wells in Harklowa field. A type of old fields of Western Carpathian Mountains.

produces from the Eocene sandstone of Ciezkowice. The development of this field is recent. A few wells were drilled in the early days, but most of the work has been done since 1924. Steep dips of the anticline limit its development in width; only the crest is capable of being made commercially productive. Toward the west the productive sandstone crops out because of the rise of the axis of the fold, which, consequently, causes the Wisznic overthrust farther west.

Approximately 15 kilometers (9 miles) still farther away is the most important group of fields of the region, in the vicinity of Krosno. They are located on four anticlines, which are, from north to south: (1) Lubatowka-Wulka, (2) Bobrka-Wietzno-Rowne-Rogi, (3) Jaslo-Krosno, and (4) Weglowka.

The first anticline is asymmetrical. It is 30 kilometers (18½ miles) in length. The Eocene occurs in its core and plunges at the two extremities. The Wulka field, and its extension, Lubatowka, are in the central and western parts.

The second anticline presents an analogous structure, but it is more eroded and the Cretaceous of the Silesian facies occurs in its core. The fields are on the eastward-plunging end of the fold. The producing formation is Eocene sandstone. These are the oldest fields in Poland. Bobrka, 5 kilometers (3 miles) in length and 200-400 meters (656-1,312 feet) in width, has been a good producer. Wells which have produced more than 10,000 tons are not rare there.

The third anticline continues from Jaslo to the east side of Krosno and has several axial culminations, or "highs." The first field, east of Jaslo, produces gas. Its structure is complicated in depth by a system of longitudinal faults.[1] Next is the Potok field, northwest of Krosno, and last is the Kroscienko field. The production in these fields is from the Eocene sandstones, and the fields are included among the most important of the Western Carpathian Mountains.

North of Krosno occur interesting complications: the fold of Chelm-Czarnorzeki thrust toward the north and the two east-west anticlinal domes of Weglowka on the top of which is exposed the Aptian.[2]

East of Krosno all these structural folds disappear. The Krosno anticline extends toward Sanok with axial outcrops of either Eocene

[1]See Obtulowicz and Wegner.

[2]Jan Nowak, "Sur la géologie du terrain situé entre Krosno et Weglowka," *Annales Société géol. de Pologne* (1924).
H. Goblot, "Sur la géologie des Karpates au Nord de Krosno," *Bull. Serv. géol. de Pologne*, IV (1928).

or Menilitic shales, which finally disappear under the Krosno formation. On this extension is the old field of Zagorz-Wielopole, where several wells yielded oil from the Krosno formation. This field is at present flooded with water and abandoned.

The fold of Chelm-Czarnorzeki gradually becomes simpler in structure toward the southeast in the form of two anticlines on which is

FIG. 8.—South-north cross section of Weglowka oil field. *Cr*, Cretaceous; *Eoc*, Eocene; *Ol*, Oligocene; *m*, Menilitic shales. Length of section, 12 kilometers (7.5 miles). After H. Goblot, "Sur la géologie des Karpates au nord de Krosno," *Bull. Serv. géol. de Pologne*, IV (1928).

exposed the Cretaceous or the Eocene; it includes the fields of Zmiennica-Turzepole, and of Grabownica-Stara Wies.

Next, farther east and in an isolated location, is the old field of Ropienka-Wankowa-Brelikow, which is about 15 kilometers (9 miles) long. It shows very special tectonic conditions. Here the productive horizon is formed by the Krosno sandstones and the Menilitic shales on the southern flank of an anticline. The reservoir, however, is not formed by the anticlinal arch, but the crest is inclined toward the southeast so that the Eocene rests on the Krosno formation. In spite of this abnormal structure this field is one of the most productive and most regular of the Krosno region, and has been active more than 40 years.

Finally, in order to complete the list, it is necessary to mention the attempts to develop the extension of the anticlines south of Sanok, resulting in the small fields of Mokre, Rajskie, Polana, and Uherce. Many wells were drilled in the Krosno formation of that region, but without positively successful results.

Thus, the Krosno region is characterized by the presence of many fields, of more or less importance, related to a series of narrow anticlines. The oil occurs in the axial culminations, or "highs," if they are not too much eroded, or more commonly in plunging noses. The principal horizons are the Ciezkowice sandstones of the Eocene and the lower part of the Krosno formation.

Table I indicates the production of the fields of the Krosno region.

Oil fields of Marginal zone.—The oil fields of the Marginal zone differ obviously from those of the Krosno region. They are almost all

TABLE I

Production of Oil Fields of Krosno Region

		Tons in 1928	Tons in 1927
1.	Kleczany	15.2	22.9
2.	Ropica Ruska, Sekowa Siary, Szymbark, et cetera	953.9	436.4
3.	Kryg, Kobylanka, Libusza, Lipinki, Pagorzyna, et cetera	10,981.5	10,523.4
4.	Harklowa	7,856.2	8,630.3
5.	Biecz	3,323.6	3,921.1
6.	Wulka, Lubatowka	1,424.7	2,052.3
7.	Bobrka, Rowne, Rogi, Iwonicz, Klimkowka, et cetera	9,978.5	10,509.5
8.	Bialkowka, Dobrucowa, Jaszczew, Mecinka, et cetera	4,480.5	1,728.4
9.	Krosno-Potok	10,967.0	11,209.2
10.	Krosno-Kroscienko	8,150.0	7,875.7
11.	Weglowka	4,702.6	3,952.5
12.	Zagorz-Wielopole	100.9	115.2
13.	Turzepole	1,339.3	1,303.0
14.	Grabownica, Humniska, Starawies	10,148.0	8,454.3
15.	Wankowa, Ropienka, Paszowa, Lodyna	14,487.4	14,940.6
16.	Mokre	432.7	419.8
17.	Polana	495.4	....
18.	Ropianka	200.6	155.5
	Miscellaneous small fields	1,455.9	1,707.2

concentrated in the deep element (over-ridden structure), with the exception of Schodnica, and include the fields of Boryslaw, Rypne, Bitkow, and Sloboda Rungurska and Kosmacz in the Pokucie region.

In almost its whole extent the deep element (over-ridden structure) is covered by the overthrust masses of the Central zone, and in those masses also are oil fields like those of Mraznica and Pasieczna, corresponding respectively with the deep deposits of Boryslaw and Bitkow, or like those of Schodnica and Strzelbice farther back. The oil fields of the deep fold are related to those of the thrust in the same way that the fields of the Krosno basin are related to those of the Magura zone.

The principal field and the most important of all in the Polish Carpathian Mountains is that of Boryslaw-Tustanowice-Mraznica, whose production represents 72 per cent of the total production of the Polish fields.

The oil is concentrated in the frontal part of the deep element, which forms a recumbent, almost horizontal fold whose normal flank has an average dip of 15°, and the normal flank is reversed and laminated. The length of the developed zone is nearly 6.5 kilometers (4 miles); its

width nearly 3 kilometers (1.8 miles). The oil is found in several horizons, the most important of which are at the base of the Menilitic shales (Boryslaw sandstone), in the Popiele formation of the Eocene, and in the Jamna sandstone of the Upper Cretaceous. Less important and less regular horizons correspond with sandstones intercalated in the Menilitic shales and in the lower part of the Eocene.

The depth of the Boryslaw sandstone, the first important horizon, ranges from 700 meters (2,296 feet) at the top of the fold to more than 1,500 meters (4,920 feet) on the flanks. The horizon of the Jamna sandstone, the deepest known horizon, is about 400 meters (1,312 feet) lower, so that the wells producing between depths of 1,400 and 1,700 meters (4,592 and 5,576 feet) form at present the larger number.

A somewhat abrupt fall of the axis at the two extremities forms a definite limit, but because of the low dip on the southern flank, productive development at Mraznica could extend more than 3 kilometers (1.8 miles) toward the top, without encountering the limit of the deposit; on the contrary, at Tustanowice the position of edge water is already known.

Recently, in a well drilled about 1,500 meters (4,920 feet) farther from the last wells of Mraznica, productive Menilitic shales have been found.

Oil produced from the Boryslaw sandstone is generally pure oil, except in a few places in Tustanowice and Mraznica, adjacent to the edge water. All of the other horizons are flooded. In the Popiele horizon the flooding occurred with exceptional suddenness and rapidity, and gradually extended westward, so that now some water is produced from all the wells of these horizons.

Attempts were made to locate a dome analogous with that of Boryslaw on the prolongation of the same fold. Toward the northwest, beyond a definite depression which limits the extension of the field, the axis rises and forms a "high" at Nahujowice. Tests at that place, however, were unsuccessful. Toward the southeast, the axis of the fold declines regularly, and exploratory wells in that direction also have been without favorable results.

On the productive fold rest the overthrust masses belonging to the border folds and to the Orow fold. The numerous wells drilled in that region have shown that the thrust surface declines very slowly, and have proved the existence of the thrust with a length of more than 4 kilometers (2.5 miles). The overthrust masses are made of successive folds of Cretaceous and of Eocene from which a very light oil of little

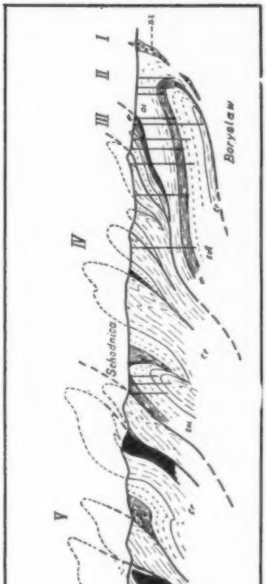

FIG. 9.—Cross section from Boryslaw to Central depression. *L.Cr.*, Lower Cretaceous; *U.Cr.*, Upper Cretaceous; *Eoc*, Eocene; *m*, Menilitic shales; *Ol*, Oligocene; *S*, Sloboda Rungurska conglomerates. Boryslaw is at east, or right, end of section. Western extremity after S. Krajewski. Length of section, 30 kilometers (18.7 miles).

FIG. 10.—Winter scene in Boryslaw field. Notice swabbing installation of productive wells.

economic importance is produced from a secondary oil deposit related to faults.

Conditions are different in the Schodnica field, 7 kilometers (4.3 miles) southeast of Boryslaw, where the structure is an asymmetrical anticline on the southern flank of the Orow fold. The Eocene forming the center of the anticline is exposed on the axial "high." Oil is produced from Eocene sandstones and from the Jamna sandstone at depths ranging from 300 to 600 meters (984 to 1,968 feet). The length of the developed zone is 11 kilometers (6.8 miles), including Schodnica and its two extensions, Opaka and Urycz-Pereprostyna, from which it is separated by unproductive depressions.

This field, which is to-day nearing depletion, has been one of the most remarkable in Poland, because of its relatively large production, shallow depth, and the good quality of its oil.[1] The Jacob well has produced 40,000 tons.

[1] K. Tolwinski, "Schodnica" and "Urycz" in "Mines de pétrole et de gaz naturels en Pologne," *Station géol. karp. Bull. 18* (1929).
St. Krajewski, "Opaka," *ibid.*

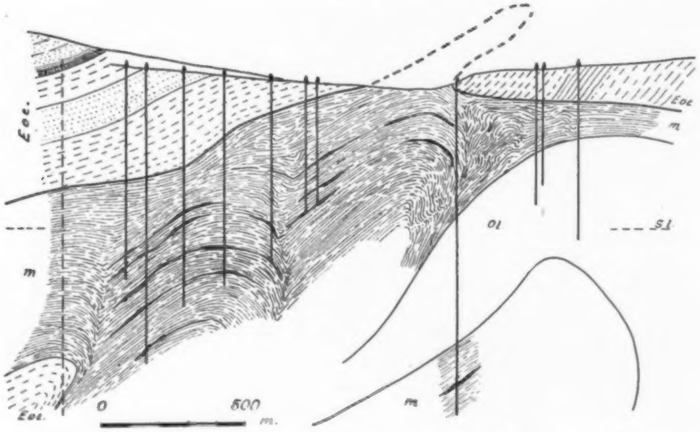

FIG. 11.—Southwest-northeast cross section of Rypne field. *Eoc*, Eocene; *m*, Menilitic shales; *Ol*, Oligocene. After H. de Cizancourt, "Rypne" in "Les gisements de pétrole et de gas naturels en Pologne," *Station géol. karp. Bull. 18* (1929). (Completed after recent documents.)

The productive region, comprising the fields of Rypne, Majdan, and Bitkow, is 75 kilometers (46.5 miles) from Boryslaw. In these fields, production is from the deep element, which appears here on the surface because of an axial elevation under the thrust. The deep structure of this element, in fact, may be studied directly and seems to be formed by two principal anticlines in the center of which the Eocene crops out,—the anticlines of Majdan and Sliwki, and between them the anticline of Bogrowka, apparent only in the Polanica formation of the Oligocene.

The Rypne field is on the northwestward-plunging end of the Sliwki anticline, which disappears under the Eocene-Oligocene thrust of the Marginal zone. The productive horizons are sandstones intercalated in the Menilitic shales, folded in secondary folds on the front of the main anticline.

The length of the developed zone is now 4 kilometers (2.5 miles) and the depths of the wells range from 600 to 900 meters (1,968 to 2,952 feet). This field, discovered in 1913, is still in active development.[1]

The Majdan field is on a dome of the Majdan anticline. The Eocene is exposed and oil is produced from its deep parts. An older field at this place, which had been abandoned for more than 20 years, was re-

[1]H. de Cizancourt, "Rypne" in "Gisements de pétrole et de gaz naturels en Pologne," *Station géol. karp. Bull. 18* (1929).

FIG. 12.—View of Rypne overthrust, along anticlinal axis. *Eoc*, Eocene; *m*, Menilitic shales.

opened and extended in 1924. The production is small, but the depth is less than 500 meters (1,640 feet), and the quality of the oil is exceptional.[1]

The Bitkow field, farther south, is very interesting tectonically. The exploited structures consist of a series of anticlines or folds, which include only the Polanica formation and the Menilitic shales, with traces of Eocene at the base. Movement occurred at the base of the Menilitic shales, followed by intensive folding. From south to north three folds are recognized: (1) the old-field anticline, formed by thin beds of Menilitic shales, resting on the Polanica formation; (2) the Dzial fold, resting on the old-field anticline; and (3) the gas fold, like that of the oil field, a large anticline in Menilitic shales. The first two folds contain oil in Menilitic shales, but the third contains gas only.

These remarkable complications influence the regularity of production, and the depth, which ranged from 400 to 800 meters (1,342 to 2,624 feet) in the old field, ranges from 700 to 1,200 meters (3,936 feet)

[1]B. Bujalski, "Majdan" in "Gisements de pétrole et de gaz naturels en Pologne," *Station géol. karp. Bull. 18* (1929).

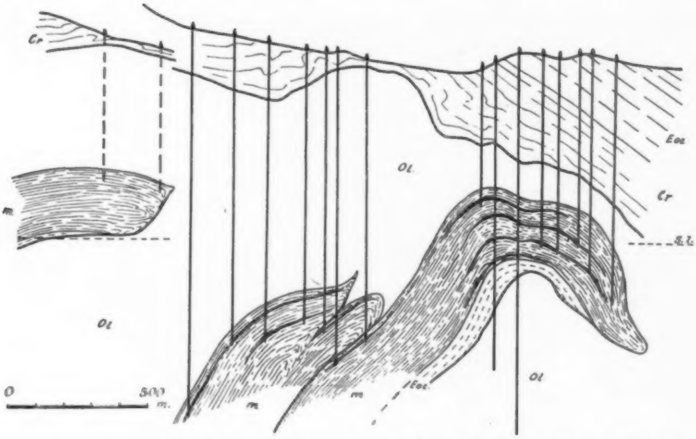

FIG. 13.—Southwest-northeast cross section of Bitkow field. Notice tectonic unconformity between exploited folds and overthrust. *Cr*, Cretaceous; *Eoc*, Eocene; *m*, Menilitic shales; *Ol*, Oligocene.

in the Dzial fold. The field does not contain water in the first two folds, but there is much water in the gas fold.

This folded ensemble is covered by the border overthrust, whose known width is more than 9 kilometers (5.5 miles). In the thrust, at shallow depth, are small wells of light oil on the prolongation of Bitkow at Pasieczna. This deposit is similar to that of Mraznica above the Boryslaw fold.[1]

The sinking of the axis southeast of Pasieczna hides the deep element for 25 kilometers (15.5 miles), but it reappears as a simpler structure in the Pokucie region, where are located the two fields of Sloboda Rungurska and Kosmacz.

The field of Sloboda Rungurska, one of the oldest in Poland, reached its maximum in 1885 and to-day is completely exhausted. It is located on a dome-like elevation of the Sloboda fold. In this field, oil was produced from the Cretaceous sandstones at depths ranging from 200 to 300 meters (656 to 974 feet).[2]

[1]B. Bujalski, "Bitkow" and "Pasieczna" in "Gisements de pétrole et de gaz naturels en Pologne," *Station géol. karp. Bull. 18* (1929).

[2]A. Alth *et al.*, "Sloboda Rungurska" in "Gisements de pétrole et de gaz naturels en Pologne," *Station géol. karp. Bull. 18* (1929).

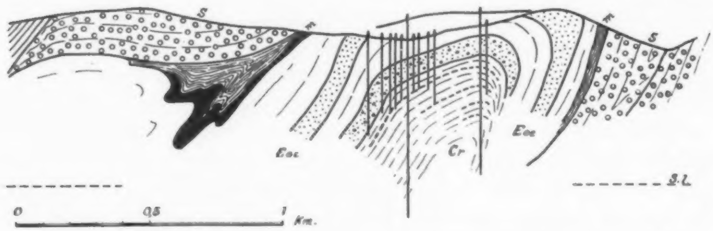

FIG. 14.—Southwest-northeast cross section of Sloboda Rungurska field. Notice tectonic unconformity between conglomerates and their substratum. *Cr*, Cretaceous; *Eoc*, Eocene; *m*, Menilitic shales with hornstone beds at base; *S*, Sloboda Rungurska conglomerates; *D*, Dobrotow formation.

The Kosmacz field contains oil in the plunging ends of one of the Pokucie anticlines, and the productive horizons are in the Eocene and the Cretaceous.[1] This field, which contains only about ten wells, is of secondary importance.

Table II indicates the present importance of the different fields.

TABLE II

PRODUCTION, IN TONS, OF OIL FIELDS OF MARGINAL ZONE

	1928	1927
19. Strzelbice	2,362.4	2,200.6
20. Boryslaw, Tustanowice, Mraznica	536,977.4	525,291.6
21. Nahujowice	91.1	247.9
22. Schodnica, Urycz, Pereprostyna, Opaka	43,980.8	40,605.3
23. Rypne, Perehinsko	17,736.9	18,454.8
24. Majdan, Rosulna, Krzywiec	4,585.9	2,540.6
25. Bitkow, Pasieczna	35,402.8	35,207.8
26. Sloboda Rungurska	1,923.7	2,025.9
27. Kosmacz	871.8	959.5

LOCATION AND DISTRIBUTION

In the preceding sections of this paper, the geology of the Polish Carpathian Mountains is outlined, and the main known deposits are reviewed. More general conclusions are now presented to explain the geographical location of the Polish oil fields and to explain the origin and migration of oil in the Carpathian Mountains. The Polish fields, which have been prospected and developed for more than 60 years, supply considerable material for a study of this kind.

[1] W. Bruderer, "Kosmacz" in "Gisements de pétrole en Pologne," *Station géol. karp. Bull. 14* (1926).

The Carpathian Mountains went through a greater tectonic change than did most other oil regions. The old geosyncline, filled with the sediments of the Flysch, was not only folded into regular anticlines and domes favorable to the accumulation of oil, but the tangential thrusts continued into a complex overthrust structure, which, *a priori*, should have been a factor in causing the migration, concentration, and preservation of the oil being produced to-day. Several authors have already studied the problem, particularly R. Zuber, Jan Nowak, W. Teisseyre, and K. Friedl.

R. Zuber[1] has stated that oil is found in the folds located immediately in front of the thrusts, whose pressure might have driven it out of the underlying rocks, as at Boryslaw and Schodnica.

Jan Nowak,[2] discussing the preceding thesis, remarks that in the Western Carpathian Mountains oil fields exist far from the front of the Magura zone. Consequently, he says, the accumulation in all these favorable structures—anticlines or domes—might have come from the depressions under the influence of the pressure of salt water.

In reality, the disposition of the Carpathian Mountains in faulted folds does not permit the preservation of the deposits in the frontal parts of the recumbent folds, generally eroded to the base of the Cretaceous; therefore, only in the anticlinal structures of the depressions of the hinterland could the mechanical conditions of accumulation have been realized. This theory is stated in a recent study by Nowak,[3] who believes that the oil regions in the Western Carpathian Mountains correspond with a zone of epi-synclinal sedimentation, so called in contrast to the epi-anticlinal sedimentation which characterizes the great anticlines and the overthrusts farther east. He states that the formation of the deposits occurred after the overthrusting, and under the influence of the circulation of waters.

Meantime W. Teisseyre[4] observed a curious coincidence. The Boryslaw oil field is on the prolongation of a transverse dislocation of the fore-

[1] R. Zuber, *Flisz i Nafta* (Lwow, 1918). (Polish.)

[2] Jan Nowak, "Le pétrole des Carpathes polonaises sous le point de vue de la géologie regionale," *Trav. géog. publ. sous la dir. de E. Romer* (Lwow, 1922).

[3] *Idem, Die Geologie der polnischen Ölfelder* (Ferdinand Enke, Stuttgart, 1929).

[4] W. Teisseyre, "Sur l'importance des dislocations transcarpathiques pour la distribution géographique et l'historie du developpement des gisements de pétrole," *C. R. Séances d. Serv. géol. de Pologne*, No. 4 (1922). (Polish.)

Idem, "Sur l'origine des traces de pétrole à Wojcza et sur la nécessité d'exécuter dans un but scientifique des forages profonds dans les dépressions subcarpathiques," *Bull. Serv. géol. de Pologne*, Vol. I, Liv. 2 and 3 (1921).

land, the line of Gologory-Krzemieniec; and Bitkow and Majdan approximately on the prolongation of another dislocation, the line of Kowalowka-Smykowce. On the contrary, he states that the transverse dislocations of the foreland are represented by posthumous dislocations in the Carpathian Mountains, and he concludes that the oil fields are to be found in the vicinity of these posthumous dislocations which in this way must have been very influential in the migration of the hydrocarbons.

Finally, it is proper to refer to an attempt of Friedl[1] to explain the geographic arrangement of the Polish oil fields on the theory that they are all connected with the deep fold, which is productive in the Eastern Carpathian Mountains, and which, covered by the overthrusts, may continue westward. However, the present tectonic conception does not take into consideration the extension of the deep fold so far toward the interior of the Carpathian Mountains.

Thus, the regional arrangement has already attracted the attention of geologists. The problem is complex and irregularities in location and relation of the oil fields are most inexplicable where the tectonics are most involved. Accordingly, the most typical examples are in the Eastern Carpathian Mountains and especially in the regions of Boryslaw and Bitkow.

The Boryslaw fold is a recumbent fold whose axis rises northwestward, forms the dome of Boryslaw, falls abruptly in the Popiele region, and forms a second dome at Nahujowice, beyond which it declines and disappears. It is to be expected that these two similar closed structures will be productive. Several exploratory wells at Nahujowice have shown that this structure contains water and showings of heavy oil. The productive horizons at Boryslaw have not been eroded; they are found at depths ranging from 200 to 800 meters (656 to 2,624 feet).

Conditions are similar in the Bitkow-Majdan region. The Bitkow-Pasieczna oil field is on a system of anticlines whose axes decline toward the southeast. Toward the northwest, however, beyond a depression, the axes re-ascend and anticlines appear in the Maniawa inlier, where they are known as the Majdan, Bogrowka, and Sliwki anticlines.

In many wells on these structures, which, *a priori*, seem favorable, there was found only water, oil showings, or very small production of very light oil, as at Majdan. In the Majdan field this oil is in the Eocene; at Bitkow it is in the Menilitic shales. This difference of structure, how-

[1] K. Friedl, "Die Entstehung des karpathischen Erdöls," *Zeits. Petroleum*, Vol. 18, No. 21 (1922).

ever, is not an explanation of the difference of the quality of the oil and the presence of water-bearing beds in the middle of the productive sandstones.

Likewise, in the anticline of Bogrowka, where the productive series at Bitkow is not eroded, only salt water and very small oil showings are found.

There are many analogous situations. The similar domes, Schodnica and Synowodzko, are on the same anticline, but only Schodnica is productive. In the Western Carpathian Mountains the location of the deposits in the regions of Krosno and Gorlice presents analogous problems which will be discussed later.

It must be stated in summary that the observed structural conditions are not sufficient explanation of the geographic disposition of the oil fields, and that other factors are to be considered. In order to determine those factors it is necessary to define the characteristics of the productive structures.

BORYSLAW REGION

The Boryslaw region includes the two structures of Boryslaw and Nahujowice. The geological map[1] shows that the structure of Boryslaw corresponds with a culmination in the border overthrusts (Orow folds) on which the Eocene synclines disappear and the Cretaceous cores are united in a single mass. This elevation is also marked by the edge of the overthrusts, which forms a concave arc toward the north. Likewise, the axis of the deep Boryslaw forms a concave arc toward the northeast.

In a similar manner, in the foreland, the southern border of the pink marls, whose general dip is northeast, is in the form of a concave arc in the opposite direction.

Finally, in that regional elevation, reappear the Sloboda Rungurska conglomerates, which, outside of this zone, are known only in the vicinity of the Pokucie elevation and stratigraphically disappear toward the north.

Reverse conditions exist, however, on the northern prolongation of the Boryslaw fold in the Nahujowice region, where the overthrust masses resume their rectilinear character, the pink marls are nearer the border of the Carpathian Mountains, the Sloboda Rungurska conglom-

[1] K. Tolwinski, "La géologie des Carpathes de Skole particulierement de la region de Boryslaw," *Station géol. karp. Bull. 8* (1925).

Idem. "Boryslaw-Tustanowice-Mraznica. Carte géologique," *Station géol. karp. Bull. 18* (1929).

erates disappear, and the Boryslaw fold continues northward obliquely to the Carpathian border.

The conclusion drawn from the preceding considerations is that Boryslaw corresponds with a regional elevation, not only of the Carpathian Mountains of the Flysch, but also of their substratum. In fact, it is necessary to include this elevation of the substratum in order to explain the presence of the Sloboda Rungurska conglomerates and the disposition of the folds in concave arcs toward the north. In reality, the present arrangement of the folds explains the presence of an obstacle at depth, an obstacle which has furnished the material of the Sloboda Rungurska conglomerates, and which later delayed the advance of the Flysch folds.

There is nothing similar at Nahujowice, where the Boryslaw fold extends without interruption in the foreland and the conglomerates disappear toward the west. The top of the fold, though higher than that of Boryslaw, is a secondary phenomenon, and there is nothing like it in the ensemble of the overthrusts and of the substratum.

BITKOW-MAJDAN REGION

The Bitkow region shows analogous phenomena, but the simplicity of structure of the overthrust conceals the complexity of the deep fold,—well known, however, through many wells, and indicated in the cross section shown in Figure 13.

The great recumbent fold of the deep zone is so contracted that secondary movement has occurred at the base of the Menilitic shales, and the higher part of the series is only a mass of piled-up faulted folds. The direction of the folds has changed also,—toward the north.

In the part of the foreland immediately in front of Bitkow, at Starunia, there are even greater complications. The Sloboda Rungurska zone, which was sinking regularly northwest from the Prut, abruptly reappears and secondary overthrusting also complicates its structure. The conglomerates of the core rise rapidly, then disappear stratigraphically toward the northwest. Here also, this disposition of the folds can be explained only by the existence of an obstacle at depth, an obstacle which has supplied the material of the conglomerates, and was the cause of the successive crushing of the Sloboda Rungurska zone and of the deep fold, which were forced to divide into a series of faulted folds.

The elevation of Majdan-Sliwki is different. The deep fold is formed by broad regular undulations which, instead of being contracted, continue freely toward the foreland.

The Sloboda Rungurska zone resumes its regular character and attains its maximum width in broad imbricated folds. The conglomerates disappear with the tectonic complications.

This disposition explains the difference between the folds crushed against an obstacle, the protruding substratum in the Bitkow-Starunia region, and the regular folds of Sliwki, Bogrowka, and Majdan, which are neither held back nor deformed by any obstacle, and which develop freely.

This is the exact repetition of conditions at Boryslaw. In these two regions, therefore, the oil is concentrated where the folds are pressed against the protruding substratum in a virgation, whose free radiating branches rise without interruption toward the foreland.

POKUCIE REGION

The Pokucie region, with its fields of Sloboda Rungurska and Kosmacz, is a typical but less remarkable example of the same phenomenon. These two structures are at the edge of the great elevation of Pokucie-Bukowina,—one a plunging nose, and the other a closed regular dome.

Here also, as at Bitkow, is a clear example of virgation in the folds of the Sloboda zone, which extends obliquely northward in the vicinity of Peczenizyn, and the anticline of Sloboda Rungurska shows traces of the secondary overthrusting which characterizes the Starunia region.

WESTERN CARPATHIAN MOUNTAINS

In the Western Carpathian Mountains, analogous phenomena are observed. The first group of oil fields in the region of Sanok-Zagorz corresponds with the rise of the folds of the depression on the west. This rise is approximately at the exterior edge of the Silesian facies of the Cretaceous, which is a facies of elevation. However, this rise is not represented by obvious tectonic deviation.

The second group of oil fields corresponds with the Krosno region, including the fields of Weglowka, Potok, Kroscienko, Bobrka-Rowne-Rogi, and Wulka-Lubatowka, which are among the most important in the Western Carpathian Mountains. The tectonic complications are similar to those already described.

The folds of Brzozow, crushed in the Weglowka region, incline in a thrust (the Bonarowka outlier) under which are the two productive anticlines of Weglowka. Toward the west, the folds resume their freedom, some of them curving in toward the north, forming the Chelm fold. The Liwocz fold keeps its northwestern direction. The virgation is here perfectly typical and the influence of the substratum undeniable. More remote effects may be seen at the north and at the south. At the

north, the folds which formed the edge of the Carpathian Mountains from Przemysl disappear at Rzeszow, but other folds continue at the south, where the anticlines of Bobrka and Wulka are close together in *en échelon* position.

These movements are accompanied by breaking, which divides the folds of the Weglowka region into blocks of different form and structure.[1]

Between Jaslo and Gorlice is a second zone of compression of the Western Carpathian Mountains. This zone may be explained by the following phenomena.

The Liwocz anticline, with one end at Weglowka, extends in a concave curve directed toward the north and continues northwestward. The Krosno anticline, near Jaslo, turns abruptly southwestward and disappears, but the adjoining Biecz anticline continues westward and northwestward, rising into the Wisznic overthrust.[2] Here, at the point of maximum compression, the anticline is broken by important transverse dislocations.[3]

The Magura overthrust continues in that direction almost as far as Jaslo, leaving some outliers,[4] and its border folds near Sekowa make a curve like that of the anticlines previously mentioned. Here are the fields of Biecz, Harklowa, Lipinki, and Sekowa.

The preceding descriptions show sufficiently the influence of the substratum upon the tectonics of the folds of the Flysch cover. The surface of the substratum shows irregularities of level; consequently, the plastic mass of the Flysch, which was being folded while advancing on that surface, was retarded in front of the elevations of the substratum, and the folds were contracted, crushed, and complicated by transverse dislocations. In front of these points, some folds were held back, and relayed by others, *en échelon.*

On the contrary, the free branches of those virgations which were not held back by anything, and which are probably separated from their roots, like the Majdan anticline, the Nahujowice fold, the Chelm, and the Ciezkowice folds, could move on freely as overthrust folds. It

[1] H. Goblot, "Sur la géologie des Karpathes au nord de Krosno," *Bull. Serv. géol. de Pologne,* IV (1928).

[2] Jan Nowak, *Zarys tectoniki Polski.*

[3] K. Tolwinski, "Dislocations transversales et directions tectoniques des Carpathes polonaises," *Trav. géog. publ. sous la dir. de E. Romer* (Lwow, 1922).

[4] *Idem.*
H. de Cizancourt, "Harklowa" in "Gisements de pétrole en Pologne," *Station géol. karp. Bull. 15* (1927).

seems inexplicable that the western extremity of a virgation marks such a movement, and not the eastern extremity. This is a result of the movement in the Carpathian Mountains spreading from west to east. The writer does not present the details of this problem, which he has treated elsewhere, relying upon arguments of stratigraphical nature.[1]

The result that is interesting because of the oil deposits is that the oil fields are grouped, as a rule, in the vicinity of the relative elevations of the substratum, and the free branches of the virgations are barren.

The term "elevations of the substratum" refers to the elevations of the topographical surface of the substratum. It is possible for some of these elevations to be connected with the tectonics, but not with the crushing of the folds, and the deviation of their direction could be considered as posthumous dislocations, of an age subsequent to the Carpathian overthrusts; on the contrary, these tectonic complications can be due only to preëxistent obstacles. Therefore, Teisseyre's hypothesis according to which the oil deposits are grouped on the posthumous dislocations common to the Carpathian Mountains and to their foreland, is not acceptable in this form.[2]

The present tectonics of the Carpathian Mountains is the result of a progressive development. The simple folds, which were formed first, and whose disposition is similar to that of the present folds of the Central depression, followed in general the undulations of the surface of the substratum, and, rising, concentrated near the points of resistance. If the concentration of the oil occurred at that time, it is evident that it could occur only in the vicinity of the elevations, those of the Flysch cover corresponding with those of the substratum. Such is the aspect of the Carpathian Mountains at the beginning of the Miocene. Meantime the substratum was still cropping out and supplying the materials of the Sloboda Rungurska conglomerates and of the pink marls.

The writer believes, however, that in the distribution of the oil fields other possible factors have to be considered; for example, the possibility of axial elevations which do not correspond with elevations of the substratum. This phenomenon could occur near the end of a fold, immediately south of which another fold could have been hindered in its movement, thus marking an axial culmination. Some oil fields may illustrate this type—for example, Rypne.

[1] H. de Cizancourt, "Quelques remarques sur la stratigraphie de l'avant-pays des Karpates polonaises orientales," *Bull. Serv. géol. de Pologne*, Vol. 5, Liv. 1-2 (1929).

[2] W. Teisseyre, "Sur l'importance des dislocations transversales....," *loc. cit.*; "Sur l'origine des traces de pétrole....," *loc. cit.*

The culminating point of the tectonic movements in the Tortonian ought not to have modified this distribution of the oil fields. The more or less overthrust and faulted anticlines previously described were carried farther away and were covered by the marginal overthrusts, at the same time that the free ends, gradually separated from their roots, were carried forward and were advancing freely upon the foreland, rising as they advanced; for example, Majdan, Nahujowice, and the folds between Tarnow and Rzeszow.

It follows from the preceding that the main period of migration ought to be placed immediately before the formation of the great overthrusts, or, more exactly, at its beginning.

Other considerations confirm this opinion. The quality of the oil in any tectonic element is almost constant, although in some places there may be exceptions. If we consider, for example, the deep zone, the oils of Boryslaw, Rypne, Bitkow, Sloboda Rungurska, and Kosmacz are similar; but at Boryslaw, as at Bitkow, the overthrust folds which surround these deposits contain small quantities of very light oil. This is a filtered oil coming from the principal oil field, and its accumulation may be related to a system of faults.

In the small Majdan field, similar oil is produced from the deep zone. This is an abnormal oil for this tectonic mass, and its origin should be sought by analogy with the preceding occurrences in a probably remote lateral secondary migration. Elsewhere the oil-bearing sandstones alternate with water-bearing sandstones, and the whole field is flooded, a condition that is especially remarkable, as it is found at the maximum culmination or "high" of the deep zone, and between the fields of Rypne and Bitkow, which contain no water although they are much lower.

At Nahujowice, there are oil showings at the top of the structure, but not in commercial quantity. This is heavy oil, seemingly oxidized, and different from the Boryslaw oil. These traces of abnormal oil, in small quantities, in flooded regions, can be interpreted only by secondary migrations subsequent to the accumulation of the principal deposits. These are the remote consequences of the last tectonic movements.

Thus, the age of accumulation of the oil may be fixed nearly at the beginning of the orogenic movements. The effect of the subsequent tectonic movements, however, was the derangement of this original disposition and the secondary migration of oil along the dislocations, thus making possible the removal of the light oil in the overthrusts and the formation of the abnormal oil fields.

This suggests the following conception of the formation of the Polish oil fields. The oil concentrated in the sandstones rose gradually into the anticlines which were being formed, and particularly into the tops of the anticlines. The concentration can not have been previous to the deposition of the last of the stratigraphic series of the element or zone considered, because in Boryslaw identical oils are found in the Cretaceous and in the Oligocene. It was, however, previous to the overthrusting. The time of concentration thus coincided with the first phase of the folding; that is, with the first breaking of the equilibrium.

In the course of time the thrusting of the folds should have only slightly modified the acquired arrangement, while the secondary migrations gave rise to the oil fields in the overthrust and to others such as Majdan and Nahujowice.

Finally, erosion no doubt modified this situation still more by the destruction of some oil fields and by the exposure of some anticlines.

ORIGIN OF OIL

Opinions have differed about the origin of oil in the Carpathian Mountains; however, it is generally agreed that the origin is to be sought in the Flysch series.

Teisseyre[1] alone offered, in 1922, the hypothesis that part of the oil, after it migrated into the Flysch cover through transverse dislocations, may have come from the substratum. The significance of these dislocations has already been mentioned. On the contrary, Nowak's recent geographical reconstructions exclude such a hypothesis, because the Carboniferous formations, the only rocks that could supply the hydrocarbons, do not extend under this region of the Carpathian Mountains.[2]

Among the authors who believe that the origin of Carpathian oil should be sought in the Flysch cover, some—for example, Szajnocha,[3] Siegfried,[4] and Friedl[5]—attempt to find the source in the bituminous

[1] W. Teisseyre, "Sur l'importance des dislocations transcarpathiques pour la distribution géographique et l'hypothese du développement des gisements de pétrole," *loc. cit.* (Polish.)

[2] Jan Nowak, *op. cit.*

[3] W. Szajnocha, "O pochodzeniu karpackiego oleju skalnego," *Czas. Nafta* (Lwow, 1899). (Polish.) "Das Erdölvorkommen in Galizien im Lichte neuer Erfahrungen," *Mitteil. Geol. Gesellsch.* (Wien, 1911).

[4] E. Siegfried, "Die Naphthalagerstätten der Umgebung von Solotwina," *Zeits. Petroleum*, Vol. 7 (1913).

[5] K. Friedl, "Die Entstehung des karpathischen Erdöls," *Zeits. Petroleum*, Vol. 18 (1922).

Menilitic shales. Others—for example, Paul[1] and especially R. Zuber[2]—have thought that the whole Flysch may have been the source.

W. Teisseyre[3] also suggested that the Saliferous formation may be the origin of the Carpathian oil. This theory, however, does not seem tenable because the great Saliferous zone of the foreland does not contain any known oil field, and further, because the whole Central depression with its many oil fields is devoid of the Saliferous.

Nowak[4] presents in his recent work a new observation of very great interest. All the oil-bearing regions of the Polish Carpathian Mountains belong to the epi-synclinal formations, that is, formations deposited in the zones where the synclinal facies was prevailing, in contrast to the epi-anticlinal formations. This introduces, for the first time, in the study of the Carpathian Mountains, the idea of a connection between the oil and the facies.

The central depression is oil-bearing in only a few regions, particularly in the region of Krosno and Sanok, that is, where the folds sink toward the southeast; also there is a series of seepages near Zabie, where the folds rise toward the southeast. This fact may be explained in two ways: either in a purely mechanical way, by admitting a general migration of the oil to the relative elevations, along the plunging structures; or in a stratigraphical way, by admitting that the oil was formed more probably on the edges of the depression, and that the migration occurred only in a secondary and limited way.

The first hypothesis permits considerable migration, which seems improbable and does not explain the absence of the oil in the oblique structures which rise laterally from the depression. In fact, in the part of the Central zone between the elevations of the Western Carpathian Mountains and the structure at Pokucie—that is, in the part corresponding with the transverse depression of Popiele—there is a whole series of plunging structures, which contain only insignificant seepages.

The second interpretation, on the contrary, necessitates making a supplementary hypothesis, postulating that the oil had been formed in the transition zone between the relative elevation and relative depressions of the same great zone of the Central Carpathian Mountains.

[1]C. M. Paul, "Die Petroleum- und Ozokerit-Verkomnisse Ostgaliziens," *Jahrb. k. k. Reichsanstalt*, Vol. 31 (Wien, 1881).

[2]R. Zuber, *Flisz i Nafta* (Lwow, 1918). (Polish.)

[3]W. Teisseyre, "Sur l'origine des traces de pétrole a Wojcza et sur la necessité d'exécuter dans un but scientifique des forages profonds dans la dépression subcarpathique," *Bull. Serv. géol. de Pologne*, Vol. 8, Liv. 2-3 (1921).

[4]Jan Nowak, *op. cit.*

Likewise, in the deep zone, the structures of Boryslaw and Bitkow are characterized by special facies of relative elevation such as the Sloboda Rungurska conglomerate, the Boryslaw sandstone, and the Kliwa sandstone. The large structure of Pokucie Bukowina does not contain much oil.

CONCLUSIONS

In the preceding chapters the writer has tried to investigate the factors which have determined the present distribution of the oil fields of the Polish Carpathian Mountains. A summary follows. The present distribution of the oil fields does not correspond with the tectonics of the overthrusts, and in great part it is independent of them. Therefore it is believed that the distribution had been determined, in general, by the embryo-tectonics of the folds. These early, simple folds were influenced by the factors of paleogeographic order; that is, by the disposition of the substratum on which they were moving. The formation of the oil was determined by the local conditions of facies; there also the paleogeographic factor must have been most influential.

Thus we come to the following sketch of the conditions of the formation and the migration of the Polish oil.

The oil was formed without doubt in the Flysch; that is, in a formation of rapid and periodic sedimentation, in not very deep seas, where chains of islands and mud flats, whose distribution was a heritage of the old Hercynian chains, supplied plentiful clastic materials and at the same time regulated the distribution of the facies. It is probable that the oil originated most favorably in synclinal zones in the vicinity of relative elevations. According to local conditions, all or part of the sedimentary series must be considered as a unit in contributing to the result.

At the same time that the Flysch was being deposited, the tectonic movements were folding it gradually into wide overthrust folds; these folds also were predetermined by the character of the substratum. Thus, the same factors which were regulating the distribution of the facies determined also the embryo-tectonics of the region.

After that time, migration of the oil could have occurred, but it seems that the breaking of the general equilibrium by the first great Tertiary movements caused the concentration of the oil into the local areas of elevation. From that time the present distribution of the oil fields was settled. The effect of the overthrusting was the separation of the Flysch from its substratum, the accentuation of its folds, and the thrust of the folds into overthrusts resting one on another; but the main

lines of the distribution of the oil fields did not change; the greatest effect of these movements was to cause some local readjustments, and to create by migration a few secondary oil deposits, whose oil, however, migrating under different conditions of temperature and pressure, is light, —different from that of the primary oil fields.

The process of the formation of the oil deposits in a region of overthrusts like the Carpathian Mountains, is not, therefore, complicated in itself, but continued tectonic development caused greater intricacy and unfortunately diminished the chances of preservation of the oil fields.

It is not the purpose of the writer to say that an analogous process could have occurred in other regions of overthrusts, but the study of a producing region developed through a period of more than 60 years, where most of the structures were explored, and where probably nearly all the oil fields are known, should contribute some explanations to the general problem of the distribution of oil in other regions of overthrusts.

This problem is to-day of small importance, but the rapid development of the oil industry, with the necessity of searching for oil under difficult conditions of depth and structure, will some day demand the special attention of geologists.

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CLAY CREEK SALT DOME, WASHINGTON COUNTY, TEXAS[1]

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ABSTRACT

The Clay Creek salt dome was discovered while surface geology was being mapped. Oil and gas are produced from sands of Cook Mountain, Mount Selman, and Wilcox age. The upward movement of this dome commenced prior to the deposition of lower Mount Selman sediments and continued at least to upper Oligocene time. An area covering the central part of this structure has been subjected to slumping since early Mount Selman time. These movements have been irregular.

LOCATION

The Clay Creek salt dome is 12 miles north of Brenham, Washington County, Texas, and 22 miles north-northeast of the Brenham salt dome (Fig. 1). It is 2 miles south of Yegua Creek, which forms the boundary between Burleson County on the north and Washington County on the south. Its name is derived from Clay Creek, which flows across its west side. This dome is in the northern part of the coastal salt-dome province.

The areal outline of the dome, as interpreted by surface geology, is in the form of an ellipse with its long axis extending 7,500 feet northeast and southwest. Interpretation of seismographic data indicates that it has a more nearly circular outline.

HISTORY

W. B. Ferguson discovered the Clay Creek salt dome in July, 1926, while mapping surface geology for the Sun Oil Company. The area of the structure was immediately leased. Five diamond drill holes were completed in November and December, 1927. On April 28, 1928, the first test for oil was commenced. This was the Schirmer No. 1, which was abandoned at a depth of 4,271 feet. It encountered no commercial showings of oil. In October, 1928, the second test, the G. F. Grote No. 1, was completed at 1,154 feet, with a daily production of 125 bar-

[1]Read before the Association at the New Orleans meeting, March 20, 1930. Manuscript received, September 30, 1930. Published by permission of Sun Oil Company.

[2]Sun Oil Company.

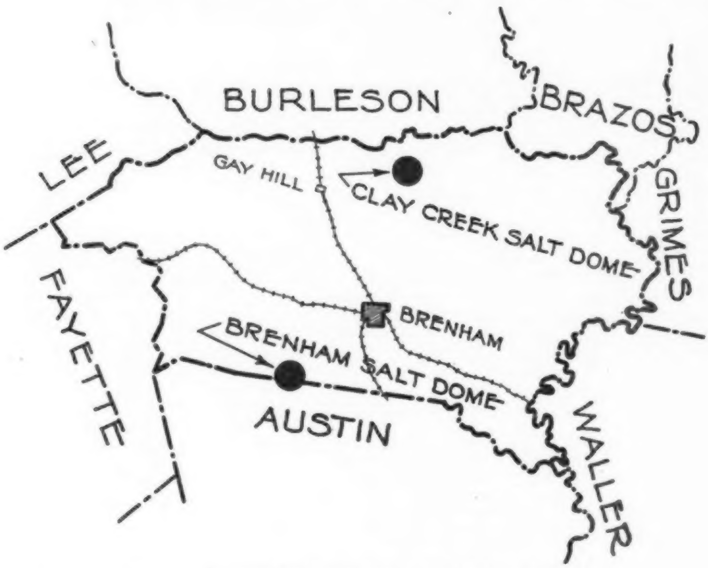

FIG. 1.—Geographical location of Clay Creek salt dome.

rels. In November, 1928, the G. F. Grote No. 2 was completed, flowing 4,200 barrels a day from a total depth of 1,345 feet. On February 1, 1930, 32 holes had been completed which resulted in 14 oil wells, 5 gas wells, and 13 dry holes. The total production from the field was 887,000 barrels of oil.

TOPOGRAPHY OF DOME

Figure 2 is a topographic map of the area of this dome (taken from the United States Geological Survey topographic sheet of the Gay Hill Quadrangle). The outline of the top of the dome is shown by a heavy line. A study of this map shows that the dome lies north of a semicircular topographic "high," which is capped by sandstones of lower Oakville age. The erosional activities of Clay Creek have formed a reentrant into its scarp. The dome itself is beneath the valley of Clay Creek, and neither topography nor drainage suggests its presence. The main channel of Clay Creek bends slightly westward as it approaches the dome from the south, but as other creeks in this area have similar drainage systems, this is not considered indicative of local structure.

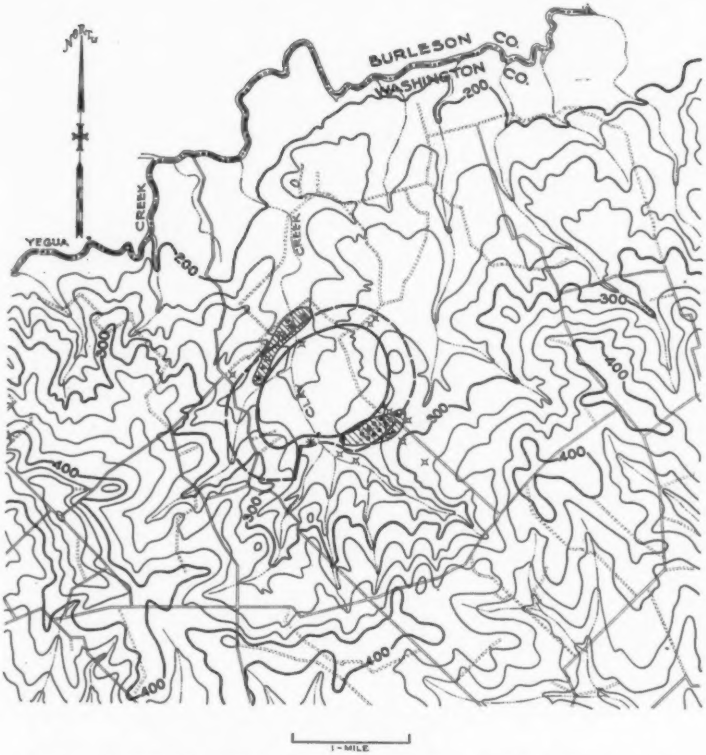

FIG. 2.—Topographic map of Clay Creek salt dome. Contour interval, 25 feet.

STRATIGRAPHY

This dome is in an area where the normal outcrops should be basal Miocene and upper Oligocene. The normal section which should be encountered in a well in this area, commencing 100 feet above the base of the Miocene, is shown in Table I.

SURFACE GEOLOGY OF CLAY CREEK

Figure 3 shows the surface geology of this dome as mapped by W. B. Ferguson, assisted by J. E. Sweeney. Over the central part of the dome are sediments of the Oakville formation, of lower Miocene age.

TABLE I

GENERALIZED STRATIGRAPHIC SECTION*

Age	*System*	*Formation*	*Thickness in Feet*	*Division*	*Description*
UPPER TERTIARY	MIOCENE	Oakville	100		Light green, calcareous shales; some coarse sandstones; re-worked Cretaceous fossils
	OLIGOCENE	Catahoula	250		Water-green, non-calcareous shales with coarse-grained sandstones; much volcanic ash
LOWER TERTIARY	EOCENE	Jackson	800		Lignitic shales; gray sandstones; a basal 200 feet of glauconitic and fossiliferous shales and sands
		Yegua	800		Lignitic gray shales; sandy shales and sandstones; several heavy beds of lignite; fossils sparse
		Cook Mountain	450	Crockett	Fossiliferous, gray shales and sandy shales
				Sparta	Gray sands and sandy shales
		Mount Selman	800	Weches	Glauconitic, fossiliferous shale; thin, fossiliferous limestones
				Queen City	Gray sands; sandy shales; a few lignites
				Reklaw	Fossiliferous gray shales; thin limestones; glauconitic beds; micaceous, thin-bedded sandy shales
				Carrizo	Gray micaceous sand
		Wilcox	2,500		Thin-bedded sands and sandy shales; thick lignite beds; thick sands
		Midway probably present but section not known			
UPPER CRETACEOUS					

*In this section the writers use the terminology of E. A. Wendlandt and G. Moses Knebel, in "Lower Claiborne of East Texas with Special Reference to Mount Sylvan Salt Dome and Salt Movements," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 10 (October, 1929), pp. 1347-75.

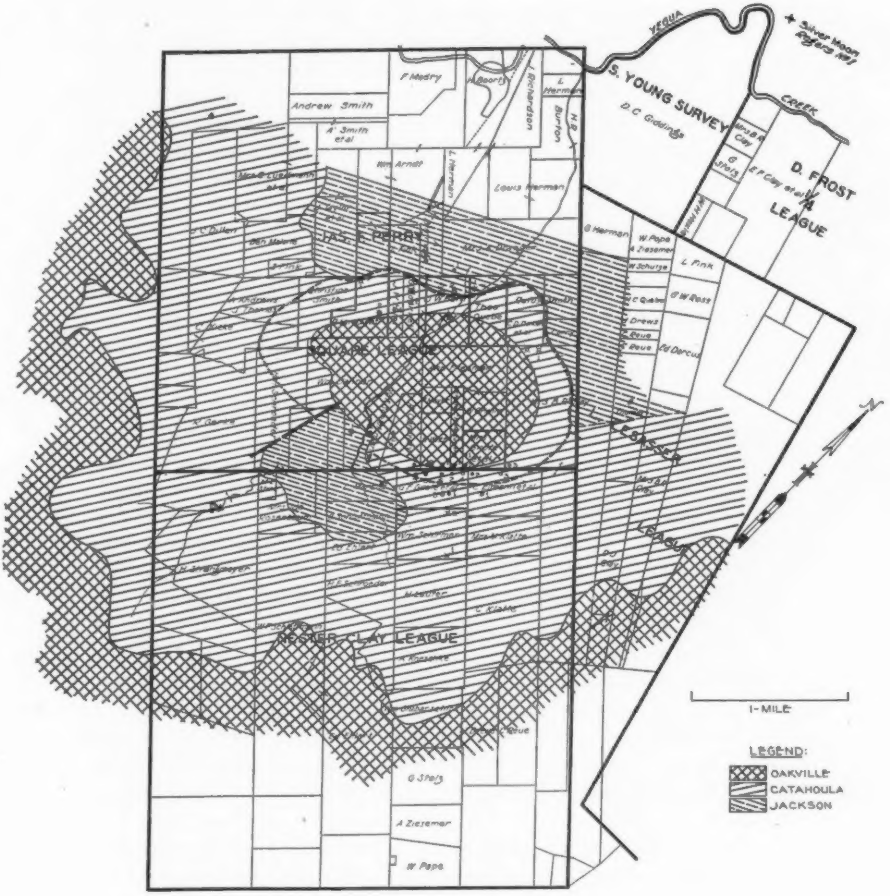

FIG. 3.—Surface geology of Clay Creek salt dome.

This central area is in the form of an ellipse with a long axis of approximately 7,500 feet, extending N. 70° E., and a short axis of approximately 5,000 feet at right angles to the long axis.

In contact with the central Oakville strata are beds of Oligocene age with the exception of approximately 1,500 feet on the south side, where the contact is between strata of Oakville and Jackson age. The Catahoula beds cover an area ranging from 500 to 1,500 feet in width on the north, northwest, and northeast sides of the dome; on the other sides, their outcrop is 1-1½ miles wide. Within the heavy dashed line the dips of the Catahoula are toward the Oakville inlier, and outside of this line the dips are away from the central area.

The Jackson outcrop on the south side of this dome is an inlier in contact with the Oakville beds on the north side, and on the east, south, and west sides with beds of Catahoula age. The contact on the west side is formed by a fault which has its downthrow on the west and whose vertical displacement has not been measured. The dips of the Jackson beds in this area are toward the south and west.

On the north side of the dome, in contact with the Catahoula beds, are sediments of Jackson age which extend to the bottoms of Yegua Creek and which are covered by recent river deposits in this direction. Catahoula sediments are present in this area, the normal Jackson-Catahoula contact being north of the bend of the creek which extends farthest north. In the Silver Moon Rogers No. 1 in Burleson County, approximately 50 feet of Catahoula strata were encountered. This Jackson outcrop is an inlier surrounded by beds of Oligocene age. The dip of the Jackson strata in this inlier is, in general, away from the central area covered by Oakville sediments.

The regional strike in this area is N. 65° E. The regional dip is approximately 150 feet per mile.

The areal geology of the Clay Creek salt dome, with the younger strata in the center and with older beds encircling them and dipping away from the central area, depicts a domal structure with its top folded or slumped down.

Around the margin of the central Oakville inlier are a few exposures of beds which dip at a steep angle toward the center of the dome.

The lowest Jackson beds exposed are those of the massive lignitic shale section of the middle Jackson. These exposures are at the part of the southern inlier which is farthest north, and at the part of the northern inlier which is farthest south.

A resumé of the facts shown by surface geology and their structural interpretation follows.

The oldest beds exposed are of middle Jackson age and are at least 600 feet above their normal position.

The area of suggested greatest structural uplift is covered by the youngest strata exposed.

The dips of the beds of lower Oligocene and of Jackson age are in general away from the central area covered by Oakville sediments.

The area in which abnormal structural conditions exist is almost circular, with a diameter of approximately 3 miles. The area of greatest uplift is not more than 1¼ miles wide.

The one large fault exposed has a strike which, if continued, would pass near the center of the area that seems to be structurally the highest.

Because these structural conditions exist in an area of known salt domes, it is logical to conclude that they indicate a salt dome. Also, from the dips of the formations exposed, it is evident that there has been no appreciable uplift of this structure since the beginning of Miocene time. One radial fault is present. Evidently slumping has occurred in the central area because of the solution of shallow salt by ground waters, this slumping evidently commencing after Oligocene time and continuing during the deposition of Oakville sediments.

SUBSURFACE GEOLOGY

PRODUCING SECTION

Production on this dome has been obtained from sands of Cook Mountain, Mount Selman, and Wilcox age, the chief producing horizons being in the last two formations.

All test holes have been cored continuously from a depth of approximately 600 feet to their total depths.

It has been possible by micro-paleontology accurately to subdivide the divisions of the Cook Mountain and Mount Selman formations as listed in Table I. This work has made it possible to interpret correctly the structural conditions encountered. The lithologic character of these divisions is so similar that such subdivisions can not be made with any degree of accuracy by the lithological method alone. Such information as is presented by cross sections and structural contour maps is based chiefly on paleontologic determinations.

Figure 4 is a log section *AA′* drawn to scale from southeast to northwest across the dome. The line of this section is shown on the figure. The following features are shown by this section.

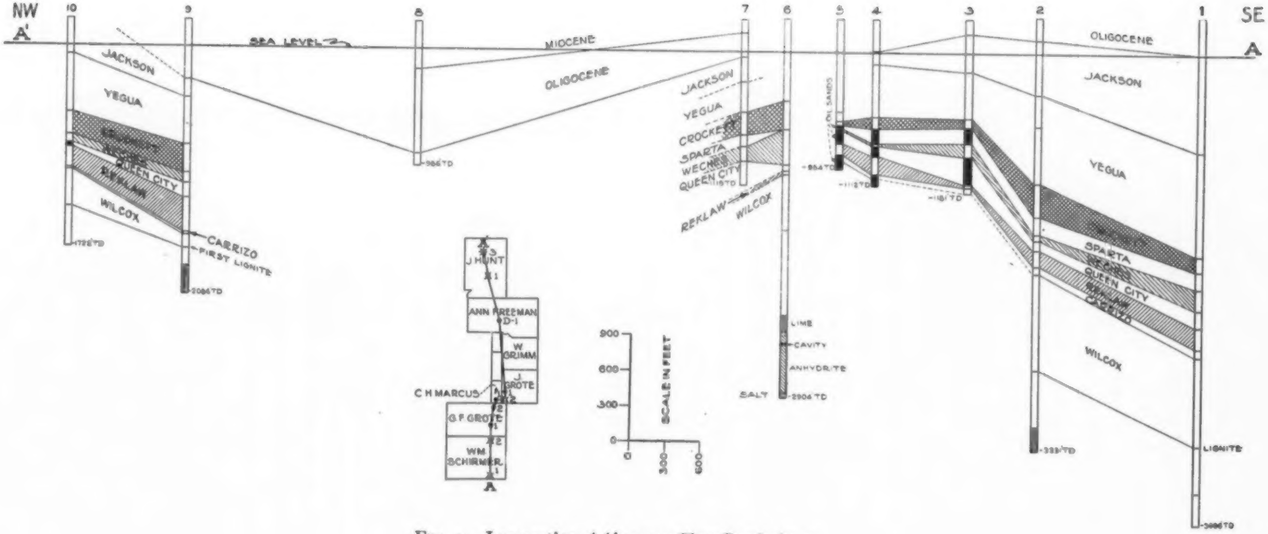

FIG. 4.—Log section AA' across Clay Creek dome.

1. On the south side of the dome from well 5 to well 1 the formations below the Miocene dip steeply southeast. The average dip of the Eocene is 28°.

2. From well 6 to well 8 the average dip of the Oligocene-Jackson contact is N. 17° toward the center of the dome.

3. From well 9 to well 8 the Oligocene-Jackson contact dips S. 17° toward the center of the dome, and from well 10 to well 9 the Jackson-Yegua contact dips S. 28°.

4. The greatest thickness of the Miocene, 404 feet, was found in well 8. The subsea datum on its base is −176 feet, which is 500 feet structurally lower than its normal position in this area. This same well encountered 702 feet of Oligocene, the subsea datum on its base being −878. This is approximately 800 feet lower than the normal position of this contact in this area, and the thickness is approximately three times that in its normal section in this locality.

5. From well 1 to well 5 the Cook Mountain-Mount Selman formations thin from 848 to 245 feet. This thinning is not distributed proportionately through the section, but a decided irregularity is noticed.

6. In well 6, 634 feet of cap rock and 50 feet of rock salt were encountered. The upper 134 feet of the cap rock was crystalline limestone, below which was 500 feet of gray-white, finely crystalline anhydrite. The cap rock showed light and dark bands which had a dip of 45°. The rock salt was similarly banded.

Log section *BB′* (Fig. 5) extends across the producing area on the south side of the dome, from the edge of production on the northeast to the edge of production on the southwest, and depicts the structural relief.

In this cross section wells 14 and 15 are the highest structurally on the Wilcox formation, and have been the most prolific producers. The formation is 2,100 feet above its normal position and produces oil and gas. Wells 14, 15, and 16 encountered no Sparta or Carrizo sands. The dip in the basal Mount Selman beds in this section is steeper than in the overlying beds.

Log section *CC′* (Fig. 6) is a northeast-southwest section across the gas-producing structure on the northwest side of the dome. No Sparta sand was encountered in wells 18, 10, and 21, and the Queen City sand was absent in well 20. The varying thicknesses of the members of the Cook Mountain section are particularly noticeable. This section shows that the structural relief in this area is much less than in the producing area on the south side, as shown on Figure 5.

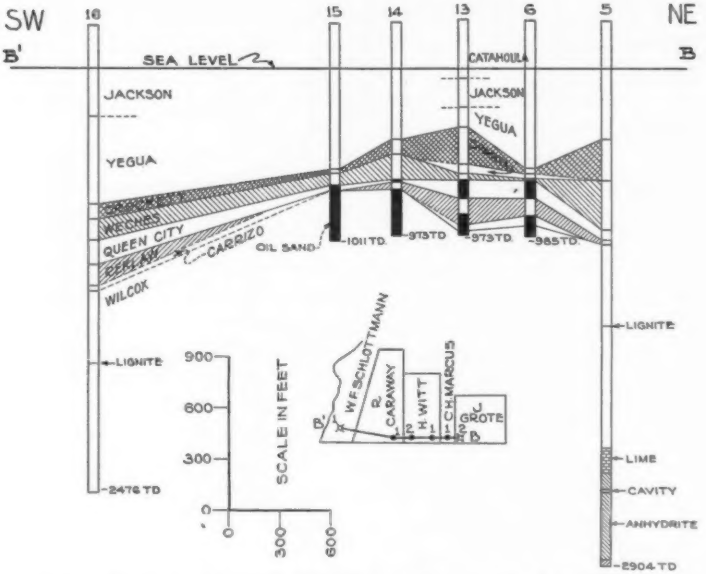

FIG. 5.—Log section *BB'* across producing area on south side of Clay Creek dome.

A study of Figure 9 shows that the section between the top of the Reklaw and the base of the Cook Mountain thins over the structurally high areas and thickens in all directions away from them.

A study of Figure 11 shows that the Yegua section thins irregularly toward the central area. This strongly suggests that during Yegua time the upward movement of the salt mass was equal to the regional downwarping, resulting in no sediments of this age being present on the top of the dome.

CONCLUSIONS CONCERNING SALT MOVEMENTS

As no Carrizo is found in the structurally highest producing wells on the south side of the dome, it is probable that the formation was not deposited, because of the existence of a local "high" at that time. The conclusion is that the salt intruded and uplifted the underlying formations prior to deposition of the Carrizo sand. The great irregularities in the thickness of the members of the Mount Selman and Cook Mountain are conclusive evidence that progressive uplift of the salt occurred

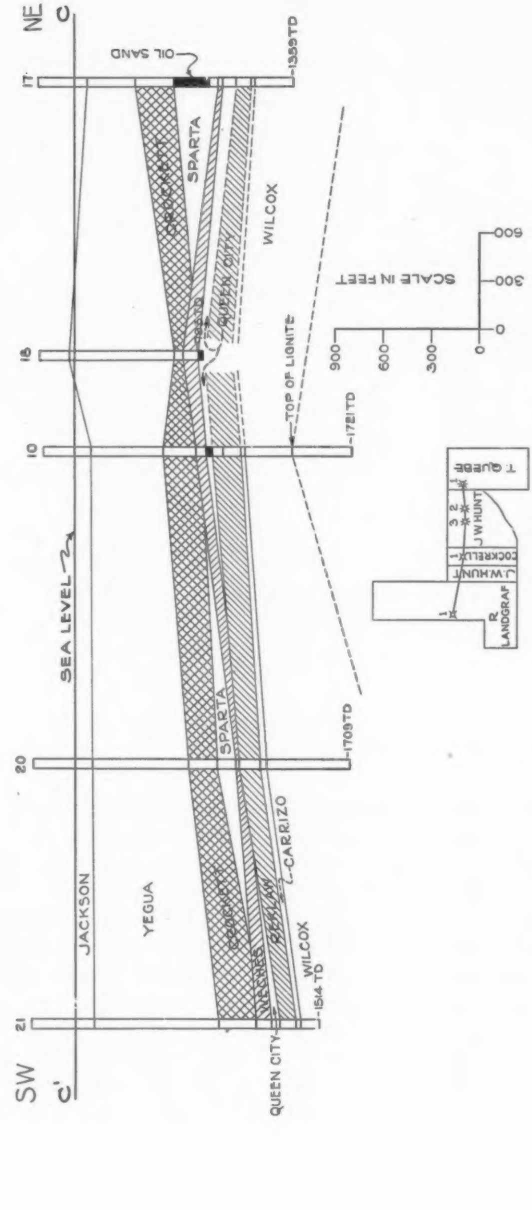

FIG. 6.—Log section *CC'* across gas-producing structure on northwest side of Clay Creek dome.

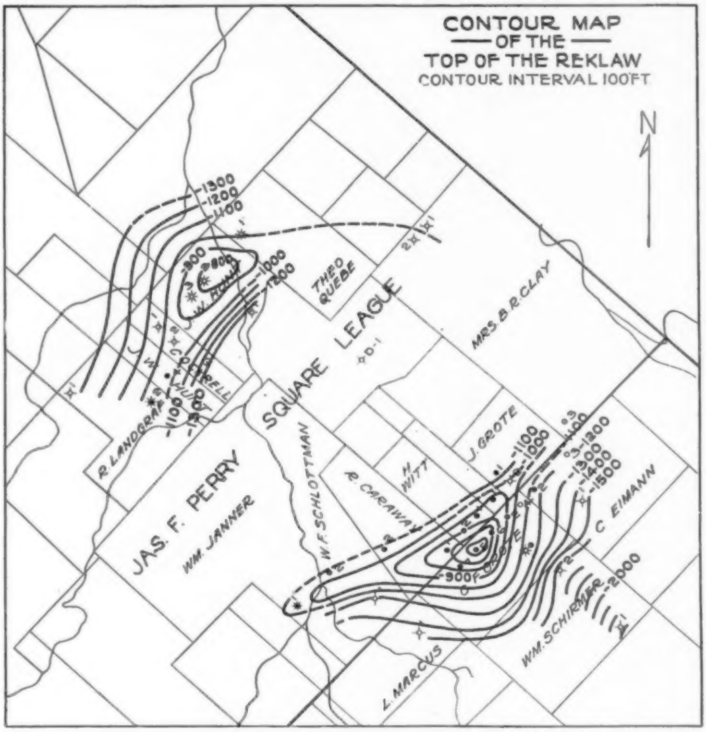

FIG. 7

during the deposition of Mount Selman and Cook Mountain sediments. During this same period there must have been slumping over the central area of the dome sufficient to explain the thickening of this section in this area, as is shown in Figure 9.

The Yegua section in Figure 11 is shown to become thinner toward the center of the dome, and it is concluded that during Yegua deposition there was continuous uplift of the salt with greatest upward displacement occurring at the center of the dome.

Insufficient data are available to determine the movements during Jackson time. It is assumed that the entire formation was deposited on the dome, inasmuch as the highest Jackson was encountered in a well drilled approximately at the center of the dome (well 8, Fig. 4).

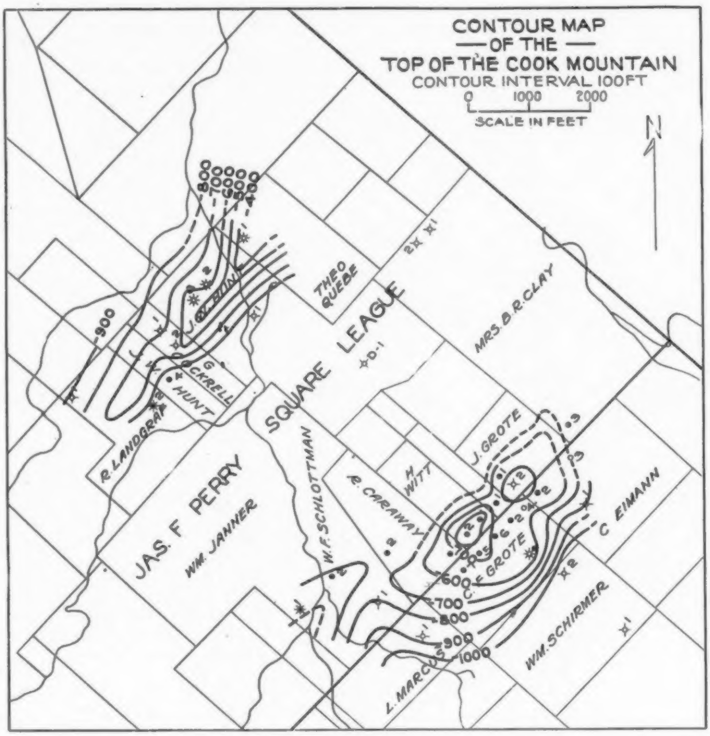

FIG. 8

Some uplift occurred during or after Oligocene deposition, and there was a subsidence of at least 600 feet of the central area.

Some subsidence of the central area occurred during Oakville deposition, and since that period a slight uplift may have occurred.

Table II presents the normal depth, the maximum indicated uplift on the dome, and the maximum downward displacement in the central area of the several divisions of the sedimentary section.

CONCLUSIONS CONCERNING FORMATION OF CENTRAL DEPRESSION

The writers believe that the evidence presented in this paper is sufficient to justify the opinion that at the close of Wilcox time the upthrusting salt mass had almost reached the surface of that time and

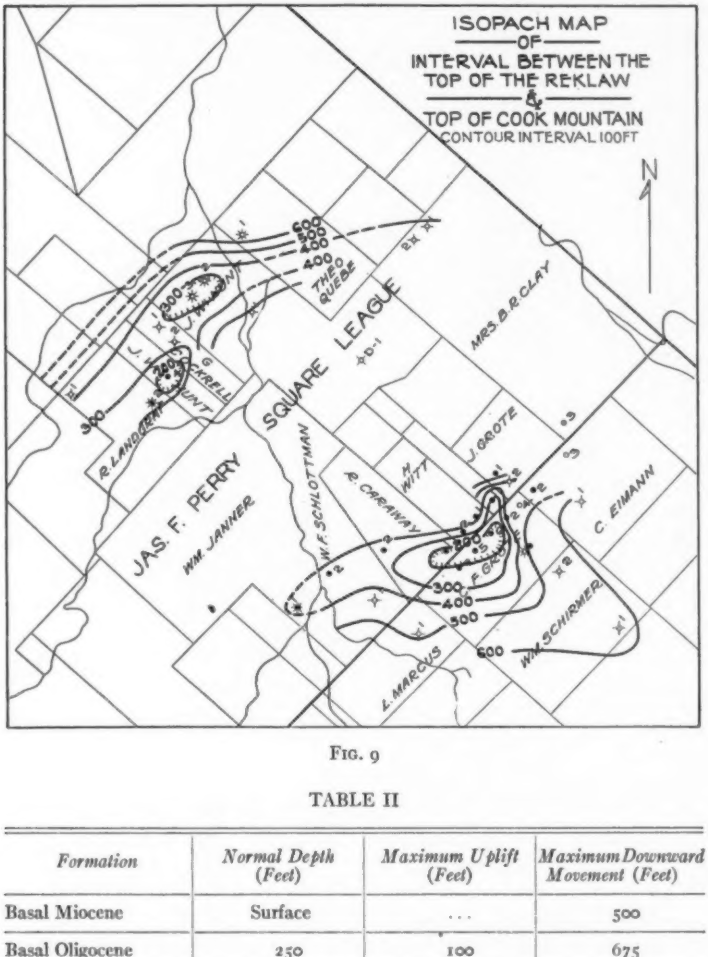

FIG. 9

TABLE II

Formation	*Normal Depth (Feet)*	*Maximum Uplift (Feet)*	*Maximum Downward Movement (Feet)*
Basal Miocene	Surface	...	500
Basal Oligocene	250	100	675
Basal Jackson	1,050	1,000	950
Basal Yegua	1,850	1,200	?
Basal Mount Selman	3,100	2,100	?

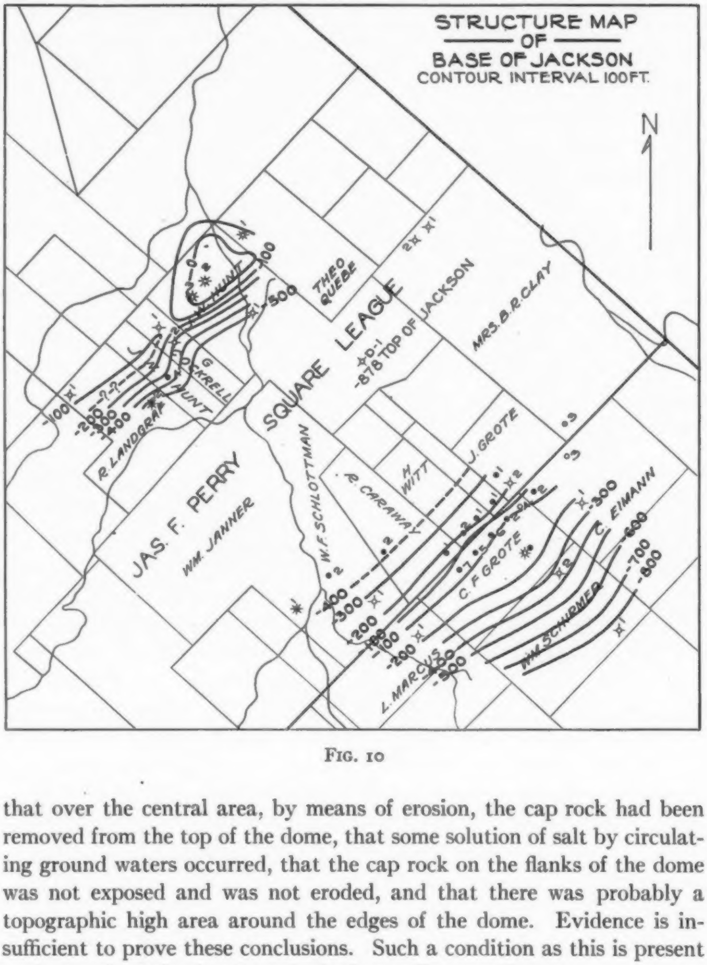

Fig. 10

that over the central area, by means of erosion, the cap rock had been removed from the top of the dome, that some solution of salt by circulating ground waters occurred, that the cap rock on the flanks of the dome was not exposed and was not eroded, and that there was probably a topographic high area around the edges of the dome. Evidence is insufficient to prove these conclusions. Such a condition as this is present to-day at the Palestine dome in Anderson County, Texas.

In the regional subsidence during Mount Selman-Cook Mountain deposition, there was upward movement of the salt core, but it was not continuous. For a considerable time ground waters may have continued to dissolve the salt in the central area, thus retarding its relative upward

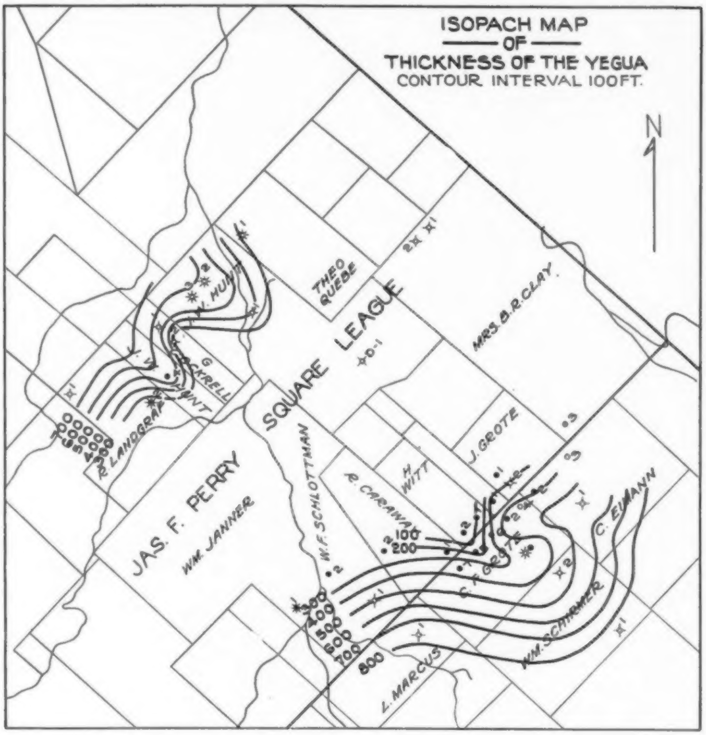

FIG. 11

movement and allowing more sediments to be deposited here than in the circular outer zone in contact with it.

During Yegua times the salt mass movement was continuously or progressively upward, with the result that little or no sediment was deposited over the center of the dome.

During Jackson time evidently there was no upward movement of the salt, as the entire upper half of the Jackson is at the surface, dipping away from the central area, and as the upper Jackson is found in the deepest well (well 8, Fig. 4) in this area.

Prior to the deposition of Catahoula sediments considerable uplift and erosion must have occurred, as lower Catahoula beds are found in contact with middle Jackson beds. There was a downwarping of the

central area, during Catahoula deposition, of at least 450 feet, which is the amount of the abnormal thickness of this section here.

During the deposition of the Oakville sediments a further downward movement of the central area occurred. Whereas no Oakville should be present here, there is at least 404 feet of such sediments.

If an entire section of Jackson is assumed to be present in the central area, its base is about 950 feet lower than normal. On the outer edge of this basin the basal Jackson is 1,050 feet above its normal position. It is, therefore, evident that solution of the salt by ground waters at a depth of at least 1,950 feet below the surface and the subsequent slumping of the overlying formation can not be the correct explanation of the downward movement.

There is a slight possibility that relatively fresh connate waters from sands on the flank of the salt mass may have been brought into contact with the top of the salt core, and that these waters could have dissolved a considerable amount of salt. The concentrated saline waters could have reached the surface through faults and fractures. The progress of such solution might have equailed the upward movement of the salt mass, but it is very doubtful if it could have exceeded the upward movement. Further evidences against this possibility are the core analyses of sands in the central area showing that the fluid contained in them is potable water.

In Donald C. Barton's review of Escher and Kuenen's paper,[1] he states that they find that a fold with an M-shaped vertical cross section results when alternate layers of clay and paraffine are subjected to a downward pressure by a ring-shaped disk while a counter pressure is kept on the central area of one-half that applied on the disk. Possibly some such combination of forces has produced a similar vertical salt-mass cross section, the low central area here being due to a relatively retarded upward movement of the salt mass underlying it.

Although the information at present is sufficient to permit the conclusions stated in this paper, the writers think that subsequent drilling may materially alter their views, probably showing that this relatively simple structure is much more complex.

SUMMARY

The following essential facts have been presented in this paper.

[1] "Experiments in Connection with Salt Domes," by B. G. Escher and Ph. H. Kuenen. (Review by Donald C. Barton.) *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 1 (January, 1930), pp. 107-08.

1. Unconformities are present in the section explored, caused by intermittent uplift of the salt mass during its deposition.

2. A central low area is present which evidently has been caused by intermittent downward salt-mass movement, except during Yegua time, when there is no evidence of downward movement.

3. Oil and gas have been obtained from Mount Selman and Wilcox sands, the first production from these formations on any salt dome in this coastal salt-dome province.

EFFECT OF SALT DOMES ON ACCUMULATION OF PETROLEUM[1]

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Houston, Texas

ABSTRACT

The source of petroleum has not been shown to have any genetic connection with salt domes. In the migration of petroleum, the major effects of a salt dome are to accelerate lateral migration and to direct migration toward the dome; the minor effect is to facilitate vertical migration through faults and fissures. Localization of accumulation in super-cap (super-salt) sands is due to simple anticlinal trapping in sands under hydraulic head; in cap-rock fields it is due to unconformity trapping and limestone porosity; and in flank fields it is due to traps of many types in sands under hydraulic head. The most important types of traps are the fault with down-throw on the down-dip side, sand lens, unconformity, and shale porosity. Lateral localization of accumulation around a dome is controlled by faulting, porosity, and continuity or lack of continuity of sands.

The structural influence of salt domes on the accumulation of petroleum has not been analyzed satisfactorily in any published discussion.

The problem of accumulation of petroleum in its simplest form may be analyzed into the subordinate problems of: (1) source of the petroleum; (2) migration of the petroleum; and (3) localization of accumulation, with its requirements of reservoir space, kind of trap, and water conditions.

The source of petroleum has not been shown to have any genetic connection with salt or salt domes. The subsurface temperatures on salt domes seem to be abnormally high; if the salt is thrust through formations, the pressure on the formations may be slightly above normal. Abnormally high temperature and pressure might accelerate generation of petroleum from its source material. There is, therefore, a faint theoretical possibility of a slight relation between salt domes and the formation of petroleum. But at a dome such as Esperson, Liberty County, Texas, the oil is found only in gently arched Miocene sands at depths of 2,300 and 3,250 feet below the surface and at a height of 3,000+ feet above the top of the salt. Below these oil sands there are 2,500+ feet of gently arched alternating beds of sand and gumbo of

[1]Manuscript received, October 27, 1930.

[2]Consulting geologist and geophysicist.

Miocene and Oligocene age. A few of the sands give showings of oil, but most of them are salt-water reservoirs. The relation between salt domes and salt-dome oil fields seems to be structural rather than genetic.

In the migration of petroleum, the effects of a salt dome are dual. Its major effect is to provide structure which should greatly accelerate lateral migration and direct it toward the crest of the dome. The normal regional dip in the Gulf Coast ranges from 75 to 200 feet per mile. The "upthrust" of the salt core has domed the sediments quaquaversally in an area extending out probably 2 or 3 miles from the edge of the salt. The radial rise in a distance of 2 miles may amount to 3,000 feet. If, as the writer believes, lateral migration occurs, it should be accelerated by these steeper dips and should be directed toward the center of the dome.

The other effect, which the writer believes to be minor, but which Roumanian oil geologists[1] and other geologists believe to be the major effect, is to facilitate vertical migration along faults and fractures. The salt and the sediments are in fault contact; accessory peripheral and radial faults are common on salt domes.[2] Transverse or vertical migration of petroleum seems definitely to have occurred on American salt domes. The flank sediments of shallow domes are very much more faulted than the sediments above very deep salt domes. The common irregularity of the occurrence of oils of different character in the flank-sand oil fields, in contrast to the regularity of the variation of the oil at domes such as Orange, Louisiana, and Esperson and Goose Creek, Texas, strongly suggests irregular migration probably along faults and fractures. The large wells in the fault gouge zone at West Columbia, Texas, suggest migration along the fault.[3] The freak high-gravity oil at Belle Isle, Louisiana, seemingly must have seeped up from great depth in, or at the edge of, the salt. The high-gravity oil which is found at abnormally shallow depths close to the salt on many domes may be oil which in part, at least, has migrated up from great depth; but the occurrence of oil at fields such as Orange, Esperson, and Goose Creek suggests that primary migration is sufficiently explained by lateral migration

[1]Karl Krejci, *Die Rumänischen Erdöllagerstätten*, particularly III, pp. 117-26 (1929). Walter Kauenhowen, "Das geol. tech. u. wirtsch. Verhältnisse des südrumänischen Erdölgebietes," *Glückauf*, No. 12 and No. 13 (January, 1925).

[2]D. P. Carlton, "West Columbia Salt Dome and Oil Field, Brazoria County, Texas," *Structure of Typical American Oil Fields*, Vol. II (Amer. Assoc. Petrol. Geol., 1929), pp. 451-69.

[3]D. P. Carlton, *op. cit.*, pp. 461-67.

and that vertical migration is subordinate. The argument of the Roumanian geologists for the upward migration of oil along the edge of the salt seems to the writer inconclusive; he has great difficulty in imagining the petroleum coming vertically up within the edge of the salt and bending its course through a vertical angle of 140° to displace water more than 1,000 feet down the stratification in sands dipping at very steep angles.

The salt-dome oil fields may be classified as: (1) super-cap (super-salt) sand fields, (2) cap-rock fields, and (3) flank-sand fields.

Localization of the accumulation in the super-cap (super-salt) sand fields is due to simple anticlinal accumulation (under conditions of hydraulic head) in sand beds between impervious gumbos. Lensing of the sands in places is a small factor. On shallow domes such as Saratoga, Texas,[1] or Batson, Texas,[2] the closure ranges from 1,500 to 3,000 feet; on a deep dome such as Esperson the closure may not be more than 500 feet. The "upthrust" of the salt has domed the overlying beds without piercing them.

Localization of petroleum in the cap-rock fields is due to limestone porosity under a cover of impervious gumbo and under conditions of probably static hydraulic head. The lime rock[3] which forms the upper part of the cap of many salt domes characteristically is permeated by a ramifying net of large and small solution channels and it contains many fractures and fissures. Cavities so large that the drill bit may drop suddenly for several feet are encountered and large quantities of hay and straw have been pumped down a well to re-establish circulation of drilling fluid. The trap is formed by impervious gumbos lying unconformably on the cap rock. The oil is underlain by salt water probably under nearly static hydraulic head. The cap-rock oil fields seem to be accumulations of a somewhat special, complicated limestone-unconformity type.

Localization of the accumulation in the flank-sand oil fields is due primarily to a fault trap in sands between impervious gumbos probably

[1] J. R. Suman, "The Saratoga Oil Field, Hardin County, Texas," *Geology of Salt Dome Oil Fields* (Amer. Assoc. Petrol. Geol., 1926), pp. 500-23.

[2] George Sawtelle, "The Batson Oil Field, Hardin County, Texas," *Geology of Salt Dome Oil Fields* (Amer. Assoc. Petrol. Geol., 1926), pp. 524-29.

[3] Objection is raised to the use of the term "limestone." The rock seems not to be sedimentary but to be a replacement deposit. Goldman uses the term "calcite" cap. On account of the large size of the deposit, the writer prefers not to speak of it by a mineralogic name.

under conditions of nearly static hydraulic head, but in places it is due to sand lenses, shale porosity, and unconformity traps.

The unconformity-trap type of accumulation is present in some of the German oil fields, such as Wietze. The basal Tertiary beds lie unconformably on Lower Cretaceous and Jurassic. The oil in the Wealden (basal Lower Cretaceous) is in sands beneath the unconformity.[1] A trap of this type may be present in American salt-dome oil fields, but this may not easily be established. Its presence is more probable at the top of the Oligocene than in the Miocene.

A small amount of oil shale is found in the Jackson black shale in the Gulf Coast region. Most of the less prolific production of oil from the Jackson is from sand lenses and sand partings in the shale, but some oil seemingly is held in the minute partings in the shale. This oil is not under hydraulic head.

Sand-lens trapping of the oil probably occurs, although it is rare. The association of a sand lens with a salt dome may be accidental, or, more rarely, genetic. The sand beds of the Gulf Coast area commonly are lenses rather than continuous sheets of great lateral extent. On a few domes, the end of a sand lens may occur correctly placed in the steeply dipping flank sediments to provide a trap of the sand-lens type. In the Persian Gulf, salt-dome mounds rise as islands; if the material of the mound is sandy, sand lenses whose formation is genetically connected with the presence of the salt dome should be deposited around it.

A trap of the plunging-anticline type may be present on the axial flanks of linear salt domes. The flank beds on the axis of linear salt domes, as Moreni and Baicoi-Tintea, form plunging anticlines on which oil deposits have accumulated.[2] A trap of some other type must be present near the flank of the salt.

The fault trap of the type having the downthrow on the up-dip side is present in American salt domes; for example, on the west-southwest flank at West Columbia.[3] It is known in other salt-dome oil fields, but it is a subordinate factor in trapping the oil.

The major factor in localization of accumulation in prolific flank-sand oil fields is the trap formed by a fault with the downthrow on the down-dip side, with sands under hydraulic head. If the much debated

[1]Alfred Kraiss, "Geologische Untersuchungen über das Ölgebiet von Wietze in der Lüneburger Heide," particularly Sec. II, Tafel 4, *Preuss. Geol. Landesanstalt Archiv für Lagerstättenforschung*, Heft 23 (1916).

[2]Walter Kauenhowen, *op. cit.*, Fig. 3.

[3]D. P. Carlton, *op. cit.*, Fig. 5, p. 456.

mechanics of the formation of salt domes is neglected, and if merely the resulting structural form is regarded, the Gulf Coast salt dome is a simple horst in which the salt is the relatively upthrown block and the surrounding sediments are relatively downthrown. If the mechanics of the formation of salt domes is considered, there is some objection to the application of the term horst to salt domes, because the original definition strictly applies to blocks which have remained up when the surrounding blocks have dropped and because the salt domes are assumed to have been upthrust through the surrounding sediments. The evidence seems to the writer, however, to indicate that on Gulf Coast domes, the oil sands have gone down more than the salt has come up. The relation of the salt to the inner edge of the flank sediments is that of a normal fault in the conventional definition of the term; the movement is vertical; the salt is upthrown relative to flank sediments, and the flank sediments are downthrown relative to the salt. As types of traps are being discussed, and not migration, the general dip of the flank sediments may be regarded as normal dip, although, strictly, it is a structural dip. Structurally, therefore, the type of trap is the same as that of the downthrown block in a faulted oil field of the type in which the downthrow is on the down-dip side, a type commonly regarded as most unfavorable for efficient trapping of oil.

Three reasons for the great effectiveness, on Gulf Coast salt domes, of the ordinarily ineffective trap of this type are as follows.

1. The oil sands are intercalated in thick beds of gumbo, that is, stiff sticky clay. Gumbo dragged and plastered across the inner edges of faulted-off oil sands should effectually seal them.

2. The drag adjacent to the edge of the salt may stretch and pinch off the end of a sand bed between thick gumbo beds and the sand bed may be forced to assume the form of a sand lensing up-dip. Such a trap is of the lensing-sand type.

3. Lateral escape of oil along the fault is impossible, for horizontally the fault is a closed circle or ellipse; lateral migration also may be stopped by radial faults or lateral lensing of the sands.

If the faults are in more consolidated sediments than the Tertiary sediments of the Gulf Coast, the probable result is that the inner edge of the sands is not effectually sealed, and the oil escapes up the fault.

The theory suggested by this peculiar accumulation of petroleum in the downthrown block on the down-dip side is that similar accumulation may be found on normal faults with the downthrow on the down-dip side which cut soft, unconsolidated sediments and which are not neces-

sarily associated with salt domes. The trap controlling the accumulation of oil in the Miocene sands at Orange is surmised by the writer to be of this type. Although the fault presumably is related to the underlying salt dome, the salt at Orange is known only from geophysical determination and must be at great depth, and the main Miocene oil sands lie between the depths of 3,000 and 4,500 feet.

Lateral localization of accumulation of petroleum around domes is irregular and its causes are not well known. Radial faulting and differential moving of radial fault blocks seemingly have been important factors. Lateral lensing, differences in porosity, and local lack of effective sealing are common causes, but ordinarily there is no clear cause for a barren octant or quadrant. The writer surmises that, to a considerable extent, conditions, perhaps structural, beyond the narrow zone of our knowledge, have converged the lines of migratory movement toward some sectors and diverged or deflected the lines of movement from other sectors. Although lensing, the sands commonly are not separate lenses but are connected in series. The interconnection or lack of interconnection of sand lenses should be a considerable factor in guiding migration.

VEGETATION AS AN INDICATOR OF GEOLOGIC FORMATIONS[1]

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ABSTRACT

Although there are exceptions, plants are commonly found to be as indicative of the formation on which they grow as are the fossils in the rocks. The most important reason for using vegetation is that contacts between formations may be mapped at a distance of several miles, because a decided change in the vegetation is noticeable. Many examples are given.

The method of mapping geologic structure by using vegetation as an indicator is increasing in importance because of the improvements being made in aërial photography and because of the adoption of this photographic method by oil companies. The vegetation that a field geologist may encounter in the course of a day's work may be almost as indicative of the geologic formation on which it grows as the fossils in the rocks. Although the writer does not wish to give the impression that plants are better than, or as effective as, fossils in mapping structure, in many areas they serve as indicators of the geologic formation. B. C. Tharp, of the department of botany, and F. L. Whitney, of the department of geology, of The University of Texas, have made observations on this subject, and the writer is grateful for the valuable suggestions made by them concerning the usefulness of plants in the correlation of geologic formations.

A special investigation on this subject was conducted by the writer, and a correlation was made between the woody plant species and the geologic formations of the Austin Quadrangle, Texas. The complete results of this work will be published later. This research was conducted for the sole purpose of determining whether plants can be depended on as indices to specific geologic formations, or whether their occurrence is so general that they are not reliable indicators. The results of this investigation showed that, in general, there is ordinarily an association of two or more dominant, woody or non-woody, plant species,

[1]Read by title before the Association at the New Orleans meeting, March 21, 1930. Manuscript received, October 18, 1930.

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with many widespread sub-dominant species, which compose the various plant societies and clans. The grass covering of the different formations is definite but generally inconspicuous, and remains almost the same; whereas the woody vegetation is apparently much more prominent and tends to change consistently with each change in geologic formation.

The area chosen for study consists of the complete central Texas Cretaceous section from the Travis Peak at the base of the Comanche series upward through the Navarro of the Gulf series. The following chart shows the geologic formations studied.

Period	*Series*	*Division*	*Formation*
Cretaceous	Gulf series	Montana	Navarro Taylor
		Colorado	Austin Eagle Ford
	Comanche series	Washita	Buda Del Rio Georgetown
		Fredericksburg	Edwards Comanche Peak Walnut
		Trinity	Glen Rose Travis Peak

Because of the similarity in lithologic and geologic characteristics, it is somewhat difficult to separate parts of the Travis Peak formation from parts of the Glen Rose formation. However, a close study generally reveals differences in the flora. For example, the Travis Peak formation is commonly represented by an association of *Quercus digitata* (Marsh) Sudw. (Spanish oak), and *Sabina sabinoides* Small (mountain cedar). Although very similar in appearance to the Travis Peak formation, the Glen Rose formation generally supports a different type of flora; it has only a few Spanish oaks and an abundance of mountain cedar. This formation generally bears, also, a very familiar small plant, *Schmaltzia lanceolata* Small (sumac). This species, generally found in abundance on the Glen Rose formation, is very rare on the Travis Peak.

The Walnut formation and the Comanche Peak are so easily recognized by their vegetation that it is scarcely possible to mistake them for any other formation. The Walnut formation is generally considered a

FIG. 1.—Typical Travis Peak vegetation.

FIG. 2.—Cedar, sumac, and oak characteristic of Glen Rose formation.

clay; the Comanche Peak consists chiefly of limestone. Although they have different lithologic characteristics, these two formations support almost the same vegetation. This is exceptional, inasmuch as most clay formations bear plants entirely different from plants on those formations which consist chiefly of limestones. Immediately on observing the dominance of *Quercus texana* Sargent (Texas oak), one would classify

the geologic formation as lower Fredericksburg in age, that is, either Walnut or Comanche Peak. If the observer were near enough to the outcrop to determine the lithologic character, he would immediately classify the formation as Walnut, if it were clay, and Comanche Peak, if it were limestone. If the observer were so far away that the lithologic character was not distinct, he would have to depend on the color of the foliage, if it were present. If the foliage were dark green, the formation represented would undoubtedly be Walnut, whereas, if the foliage were light green, the formation would probably be Comanche Peak. This is because of the differences in the soil of the two formations, the clay producing a rather rich soil, and the soil produced from the limestone being relatively poor in quality. If these two formations were represented on a distant hill, they might be easily recognized because of their distinctive massiveness and their peculiar appearance and color. The contact between the Walnut and Glen Rose is easily recognizable because of their entirely different floras. It is difficult to confuse the decidedly different woody vegetation represented on the Comanche Peak and Edwards formations, and the two may be distinguished at a long distance.

The Edwards formation, which consists chiefly of limestones, supports an easily recognized, characteristic vegetation, different from that of any other formation. The woody plant species consist chiefly of *Quercus fusiformis* Sargent (mountain scrub oak), which forms dense thickets, known as "oak shinneries." The plant seldom grows on other formations and never in the abundance in which it is found on the Edwards formation. A scarcity of other woody plants growing on the Edwards makes this type of oak appear more abundant than it really is.

Near the middle of the Edwards formation, in Comal County, a bed of gravels and clays is found between massive limestones. This zone in the Edwards supports *Prosopis glandulosa* Torr. (mesquite), instead of mountain scrub oak. The occurrence of the characteristic oak, above and below the outcrop supporting mesquite, indicates that the formation is Edwards. This bed may thus be recognized for miles. From a distance it appears as a light green band between two dark green masses. Farther north in central Texas, however, this stratum of soft material disappears and with it the mesquite, leaving only the small mountain live oak as characteristic of the Edwards.

The Georgetown formation, which, in central Texas, consists chiefly of soft, nodular limestones, supports the mountain cedar and *Schmaltzia trilobata* Small (skunk bush), the latter easily distinguishable because it grows to the exclusion of almost everything else. Although a few moun-

FIG. 3.—Typical vegetation of Walnut formation.

FIG. 4.—Texas oak dominant on Comanche Peak formation.

tain cedars occur on most of the Washita formations in central Texas, only on the Georgetown is there such a dominance of the species. The skunk bush is commonly associated with this species. Both plants are easily recognized.

The Del Rio formation in central Texas consists almost entirely of clays. As on most of the other soft formations of the Cretaceous of this region, the woody plants which thrive in abundance are the mesquites.

FIG. 5.—Oak shinnery of Edwards formation.

FIG. 6.—Mountain cedar and sumac characteristic of Georgetown formation.

Rarely do any other woody plants grow on the Del Rio. Inasmuch as this is not the only formation which supports mesquite, its own flora is not diagnostic and other means must be used to distinguish it. Generally this may be done by observing the type of vegetation which occurs on the formation above or below the formation being studied. The Buda, the formation above the Del Rio, is characterized by a dominance of *Ulmus crassifolia* Nutt (elm). Below the Del Rio, the Georgetown

supports, dominantly, mountain cedar. As this association of plants is not found elsewhere in the Cretaceous section, one has only to notice the vegetation above or below the Del Rio in order to distinguish it from all other mesquite-bearing formations.

FIG. 7.—Del Rio formation represented by mesquite trees.

The Buda, the highest formation in the Lower Cretaceous, consists chiefly of massive limestone. The woody vegetation supported by the formation is very distinctive. The most diagnostic woody plant is the common elm, which is so prevalent that it may be designated the single dominant species for the Buda limestone. This does not mean that elms do not occur on any other formation, but that they are associated more abundantly with the Buda than with any other formation, and that they grow more profusely on that formation than any other species. This vegetation is very distinctive because of the occurrence of mesquites on the formations immediately below and above it. Generally, the vegetation of the Buda forms a dark green band between the light green bands of the Del Rio and the Eagle Ford.

The Eagle Ford, the lowest formation of the Upper Cretaceous of central Texas, consisting almost entirely of shales, is classed as one of the soft formations. Inasmuch as its principal plant is the mesquite, the Eagle Ford flora is very similar to the Del Rio or to the members of the Montana division, namely, Taylor and Navarro. As in the Del Rio formation, there is no definitely diagnostic plant, but, by noticing the nature

FIG. 8.—Elm trees dominant on Buda formation.

FIG. 9.—Vegetation characteristic of Eagle Ford formation.

of the flora on the formations below and above the Eagle Ford, the observer is able to decide immediately that the formation represented is Eagle Ford. This is true because in the entire section of the Cretaceous in this region there is not another such succession of beds.

The Austin formation in this region consists almost entirely of chalky limestone. Wherever it is encountered, there is almost invariably

a dominance of large *Quercus virginiana* Mill (live oak). Whether the chalk is hard or soft, this species is generally fairly abundant and may be found in profusion. The occurrence of these large live oaks on the Austin is so characteristic that they may be reliably used in structure mapping.

The Taylor formation, almost entirely marls and clays, is one of the soft formations supporting mesquites in abundance almost to the ex-

FIG. 10.—Large live-oak trees indicative of Austin formation.

FIG. 11.—Mesquite and cactus association characteristic of Taylor formation.

clusion of other woody plants. It is difficult to distinguish the Taylor from the other formations. For example, its lithology is almost exactly like that of the Navarro. Both formations are thick and, to the casual observer, appear almost the same. A close examination, however, shows that the Taylor supports very few herbaceous or woody plants, —fewer than the Navarro above. Up-dip from the outcrop of the Taylor, the abundance of live oaks indicates definitely the occurrence of the Austin formation.

The Navarro, the highest formation in the Cretaceous of central Texas, is represented by approximately 400 feet of marls and clays. It may be difficult to distinguish this formation from other formations in contact with it, although, after close inspection, many different characters are discernible. The vegetation of the Navarro is rarely confused with that of the Taylor. The Navarro formation supports several plants which grow in abundance and which do not occur in the generally

FIG. 12.—Dense mesquite-cactus chaparral characteristic of Navarro formation.

similar Taylor marl below. The following plants in association are characteristic of the Navarro: *Prosopis glandulosa* Torr. (mesquite), *Opuntia lindheimera* Engelm. (prickly pear), *Condalia obovata* Hook., and *Zyzyphus obtusifolia* A. Gray. This peculiar association of plants is not found on any other part of the Cretaceous section. If they should be found to occur together elsewhere, they would not be as abundant as they are on the Navarro formation.

Correlations similar to the foregoing might be made for the formations in the Tertiary and other geologic periods.

USE OF PLANTS TO LOCATE GEOLOGIC STRUCTURES

It is remarkable how closely plant changes conform to contacts or changes in formations. For example, a few miles north of the town of Georgetown, Texas, a fault is parallel with a road. While riding along this road one day, the writer noticed an abrupt change in vegetation, from mountain cedars to small scrub oaks. Both seemed to grow to the same line and stop. The change in vegetation seemed to follow a straight course. Knowing that cedars alone characterized the Georgetown formation and that scrubby live oaks characterized the Edwards formation, the writer predicted that a fault would be found between these two formations. Later this proved to be the fact.

On the Gulf Coastal plain in Texas it is ordinarily difficult to map structures, particularly faults in Tertiary formations where sandy material prevails. The writer has been able to map several faults by finding a single plant species, namely, *Daubentonia longifolia* DC. (rattle-bush), which grows only in very moist conditions. This plant may be noticed in a sandy field where the actual formation is hidden by many feet of alluvial material. Although there is no surface indication of the fault, enough water may be forced up the fault plane to cause this bush to thrive. There may not be any other specimens within several miles.

The writer has been informed by reliable geologists, who have spent much time in West Texas, where there is much igneous material, that the different kinds of material in this region can be mapped by the use of vegetation, and that this method is especially useful around the edges of the uplifts where the sedimentary rocks occur.

Through north-central Texas the Pennsylvanian-Cretaceous contact is distinctly marked by a growth of post oaks and black-jack oaks on the Cretaceous side of the contact. Aërial photographs show an almost perfect map of the contact. Several anticlines and synclines in Montague County, Texas, are revealed very distinctly because of the curves in the Pennsylvanian-Cretaceous contact. These structures were immediately found by noticing the curves in vegetation corresponding with the contact.

On a small anticline in Hays County, Texas, mesquites associated with the Eagle Ford shale were noticed on the top of a hill. On the sides of the hill were live oaks belonging to the Austin chalk, which should have been above the Eagle Ford. The anticline represented here could

be noticed for a long distance because of the peculiar position of these plants.

SUMMARY

The writer has endeavored to show the usefulness of vegetation as an accurate means of mapping geologic formations. When a complete map of the Austin Quadrangle, made by mapping the different characteristic plants or associations of plants, was compared with a geologic map of the same region, it was found that the contacts between the different types of vegetation and the contacts between the corresponding geologic formations agreed almost exactly. The development of aërial photography will doubtless increase the importance of this method of geologic mapping, especially whenever it is necessary to produce a map of a large area in a limited time. Vegetation of different types appears on aërial photographs in different tones. The new stereoscopes made especially for the examination of aërial photographs show the height of the trees as well as the relief of the land. The writer does not believe that this method can be used in all parts of the country, but he is sure that in many places valuable results in mapping geologic structure can be obtained by the use of plants as indices of geologic formations.

GEOLOGICAL NOTES

GRAPHIC SOLUTION OF STRIKE AND DIP FROM TWO ANGULAR COMPONENTS

The geological note with this title on page 1211 of the *Bulletin*, Vol. 13, No. 9 (September, 1929), was recently noticed. This suggested a somewhat simpler graphical method of determining the strike and dip from two or more components.

The problem is identical with that of determining the direction and magnitude of any vector when its components along two different directions are known. The direction perpendicular to the strike and the magnitude of the vertical angle correspond with the direction and magnitude of a vector.

Consider first the problem of determining an ordinary vector from two components. Suppose that the components are known along two directions, OA and OB, as OA' and OB' respectively (Fig. 1). Any vector originating at O and ending on a line perpendicular to OA through point A' will have the component OA'. Similarly, any vector originating

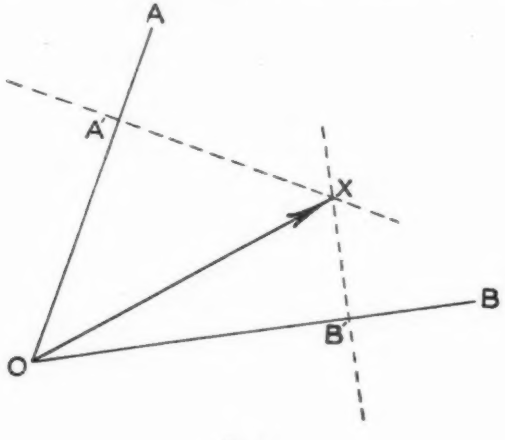

FIG. 1

at O and ending on a line perpendicular to OB at B' will have the component OB'. The only vector which can satisfy both of these conditions is the one originating at O and terminating at the intersection of the two perpendiculars. Therefore, the desired vector is OX (Fig. 1).

Let us apply this method to the problem given in the article referred to (page 1211). The observed bearings and dips, after conversion to the proper quadrant for negative angles, were S. 20° W., 3° 40′; and S. 60° E., 4°. Lay off the line OA in the direction S. 20° W. On this, scale off OA', so that this is numerically proportional to 3° 40′, and erect a perpendicular. Lay off line OB in the direction S. 60° E., scale

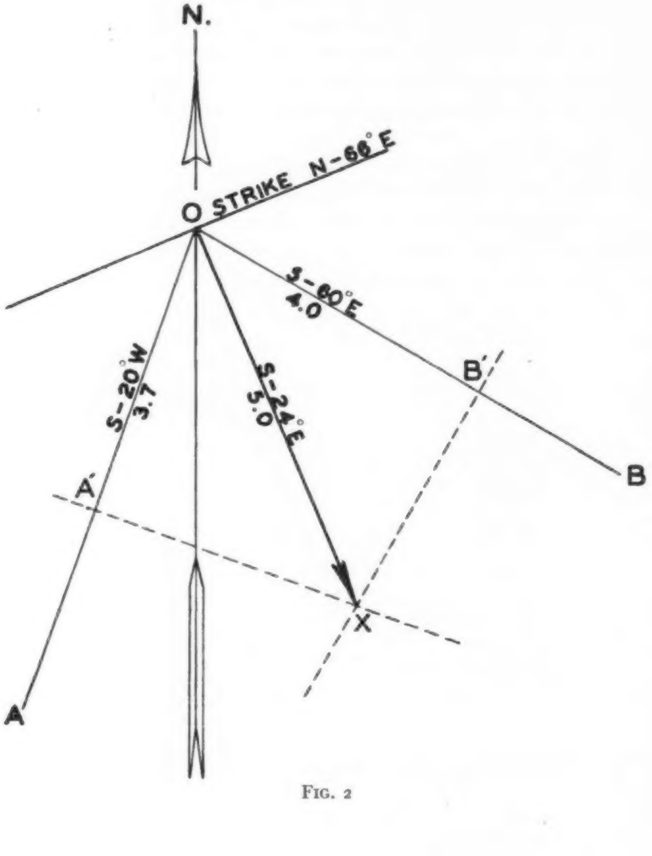

FIG. 2

off OB', proportional to 4°, and erect a perpendicular. The intersection of these perpendiculars gives the vector OX, the length of which is proportional to 5° (the desired dip), and the direction is S. 24° E., giving the strike as N. 66° E. (Fig. 2). These values are the same as found by the previously described method.

The method described here may be used easily to determine an average value of the dip and strike from several independent measurements of dip components. For example, suppose measurements give the following components: S. 51° W., 4° 20′; due south, 15° 40′; S. 41° E., 18° 20′; S. 66° E., 13° 40′. From a common point (Fig. 3), lay out lines having the observed bearings, scale off distances proportional to

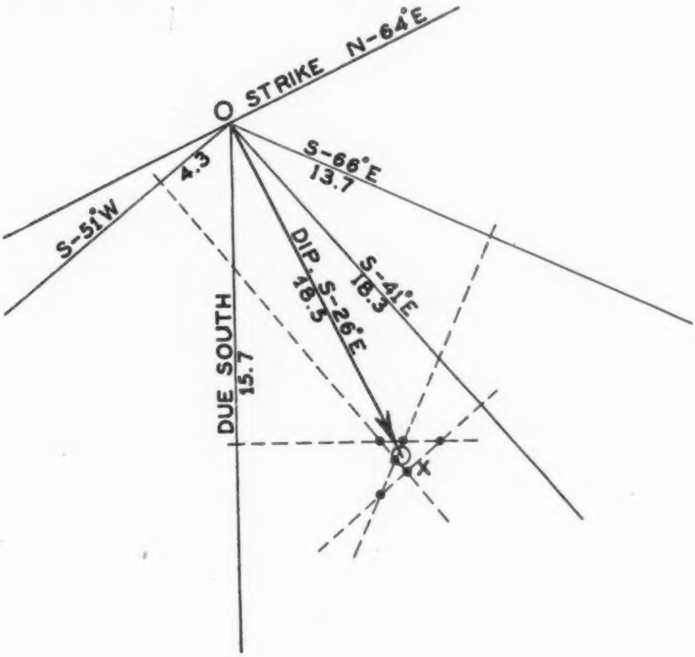

FIG. 3

the observed dips, and erect perpendiculars as previously described. Then the intersection of any perpendicular with any other perpendicular

is a solution from a pair of observations. The six small dots represent the various solutions. The single circle is an estimate of an average solution. This gives the average result, OX, as a dip of 18° 30′ SE., strike N. 64° E. (Fig. 3).

The only tools needed for any of these operations are a protractor and scale.

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November 8, 1930

DISCUSSION

TIME *VERSUS* TEMPERATURE IN PETROLEUM GENERATION[1]

David White, in a recent issue of this *Bulletin*,[2] has given a concise summary of Maier and Zimmerly's important work on the relation of time and temperature in the generation of bitumen.[3] In this investigation Maier and Zimmerly demonstrated that, in the particular oil shale they studied, the conversion of the organic matter to bitumen, that is, to a form soluble in carbon tetrachloride, behaved as a chemical reaction of the first order; therefore, it was not solely dependent on temperature, but was also a function of time. This means that the reaction would take place at any temperature, but the lower the temperature, the longer the time.

This is the major contribution of Maier and Zimmerly's paper, and if similar work on deposits of other types shows it to be characteristic of sediments in general, it will be a great step forward in our study of the origin of petroleum. The further investigation of this subject now being undertaken by Miss Stadnichenko and David White should prove most valuable.

The rate at which the reaction takes place at temperatures prevailing underground is of great interest to geologists. This particular phase of the problem did not occupy the special attention of Maier and Zimmerly in writing the paper; but they determined the formula for calculating the rate at any temperature, and in support of their observation that no organic matter was converted to bitumen by heating a sample for 90 days at 100° C., they mentioned that it would take 8.4×10^5 years for conversion of 1 per cent of the organic matter at that temperature. However, the 8.4×10^5 is incorrect. It should be 8.4×10^4, or 84,000 years.

The time needed for a 1 per cent conversion lengthens very rapidly as the temperature falls below 100° C. At 80° C., or 176° F., it would be 2,000,000 years, and at 60° C., or 140° F., it would be 67,000,000 years.

These calculations are based on a single investigation of an oil shale, and have not yet been corroborated by additional studies of other sediments; therefore, as pointed out by White, they are qualitative. Furthermore, the reaction is that of formation of bitumen, not oil or petroleum. However,

[1]This paper contains preliminary results of an investigation on "The Origin and Environment of Source Sediments," listed as Project 4 of the American Petroleum Institute research program. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by John D. Rockefeller. This fund is being administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council.

[2]David White, "Exchange of Time for Temperature in Petroleum Generation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 9 (September, 1930), pp. 1227-29.

[3]C. G. Maier and S. R. Zimmerly, "The Chemical Dynamics of the Transformation of the Organic Matter to Bitumen in Oil Shale," *Bull. Univ. Utah*, Vol. 14, No. 7 (1924), pp. 62-81.

some of the times and temperatures of the reaction are compatible with the geologic conditions under which petroleum develops. Consequently, the matter merits careful consideration by geologists.

In order to ascertain whether the same phenomenon was characteristic of modern marine muds, rich in organic matter, and presumably potential future source beds of petroleum, the writer analyzed several recent sediments by the same method. In this work he was much aided by the personal advice and suggestions of C. G. Maier.

The recent deposits behaved in much the same manner as did oil shale. For example, a sediment from Lake Maracaibo containing approximately 5 per cent organic matter, had about 3 per cent of its organic content converted to bitumen in 12 hours at 280° C.; about 9 per cent in 12 hours at 300° C.; and about 13 per cent in 2 hours at 339° C. Qualitatively, this is the same phenomenon reported by Maier and Zimmerly, but the data were not sufficiently satisfactory to determine the constants governing the rate of reaction and it was impossible to calculate the rate of conversion at temperatures that would prevail at the depth at which the sediments would probably be interred during generation of petroleum.

A similar transformation seems to take place in sediments while they lie buried in the earth. The writer has not yet studied sufficient past deposits to justify a generalization, but in those he has analyzed, the bitumen content, that is the part soluble in carbon tetrachloride or ether, is several times greater than in recent sediments of comparable organic content. This indicates that in past deposits some of the organic matter has been converted to bitumen. In fact, it suggests that the formation of bitumen perhaps is an intermediate step in petroleum generation.

PARKER D. TRASK

PRINCETON, NEW JERSEY
October 27, 1930

PENNSYLVANIAN CLIMATES AND PALEONTOLOGY

I was deeply interested in the paper by Albert W. Giles on "Pennsylvanian Climates and Paleontology" in the October, 1930, issue of the *Bulletin*. At present I wish to remark only on the paleogeographic map of the Pennsylvanian on page 1289.

Judging from many years of personal work in the Australian region, I should say that it is necessary to widen, very considerably, the gulfs in the Gondwana continent on both eastern and western flanks of the Australian province. Recent work particularly calls for this. The sea also occupied part of the eastern side of Tasmania at this time and the gulf shown in this vicinity should be deepened.

Again, my own examination of Madagascar leads me to believe that the southern ocean may have pushed in as a bay somewhere near the southern extremity of the Mozambique Channel. There is also some paleontological evidence which tends to show a closer connection between Madagascar and the Indian region than with the much nearer African region,—an interesting question which is deserving of closer study.

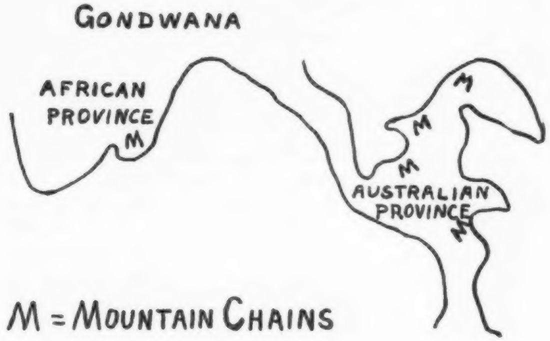

FIG. 1

However, these paleogeographic maps, of necessity, can be only approximate indications of these ancient distributions of land and water. More detail and more accuracy will come as geologists find opportunities to study more carefully the less known areas.

ARTHUR WADE

19 BASINGHALL STREET
LONDON, E. C. 2
November 17, 1930

REVIEWS AND NEW PUBLICATIONS

"Petroleum Reserves of Madagascar." By C. P. NICOLESCO. *La Revue Pétrolifère* (Paris), Nos. 388, 389, 390 (September 6, 13, and 20, 1930), pp. 1225-31, 1257-62, and 1289-94. Two tables, one geologic map, and two figures.

This is a summary of all previous work on the petroleum reserves of Madagascar, and of many observations made by the author during his trip in the petroliferous districts of Sakalave in western Madagascar.

This review includes the following chapters: Introduction; General Notes; Reconnaissance of Petroleum (surface and subsurface); Origin of Petroleum in Madagascar (organic *versus* volcanic); Accumulation of Petroleum (in place of origin or by migration); Age of Petroleum on the Island (age of reservoir rocks, source rock, and concentration); Chances of Encountering Commercial Petroleum Resources; and Conclusions.

The petroliferous formations on the surface are found in a belt approximately 1,200 kilometers long and 10-20 kilometers wide, extending from Diego-Suarez on the north end of the island to the vicinity of Eular on the south end, between the crystalline mountains of Bongolava on the east and a limestone outcrop on the west (Fig. 1). These formations are found principally in the beds of Ankavandra (upper Erias) and are composed of sands and conglomerates,—not of schists, as was believed prior to 1921.

Reconnaissance for petroleum in Madagascar has been conducted with two purposes: to obtain petroleum on the surface from gray bituminous shales, and to discover underground reservoirs and produce liquid petroleum from the petroliferous sands.

On the surface it is possible to exploit petroliferous shales by stripping operations and by underground mining, the shales yielding about 100 liters of crude oil per ton. The volume of these formations, figured only to the depth of 20 meters, is estimated at several billions of tons. Considering the present state of these hydrocarbons, their physical and chemical characteristics, and those of their various fractions, and considering the methods of treatment on a commercial scale, including mining, transportation, and refining, it has been figured that the enterprise would pay provided it was organized on a solid financial basis.

The petroleum underground must be reached by drilling wells. The few wells drilled so far gave negative results because the surface structures were not considered. Contrary to the opinion expressed in most of the earlier reports, the petroliferous formations have been affected by diastrophic movements, including folds, and include as many sands as shales and clays; in other words, they include the two principal conditions necessary for concentration and conservation of petroleum. There are seemingly petroleum deposits at different depths, some of them of secondary origin, resulting from

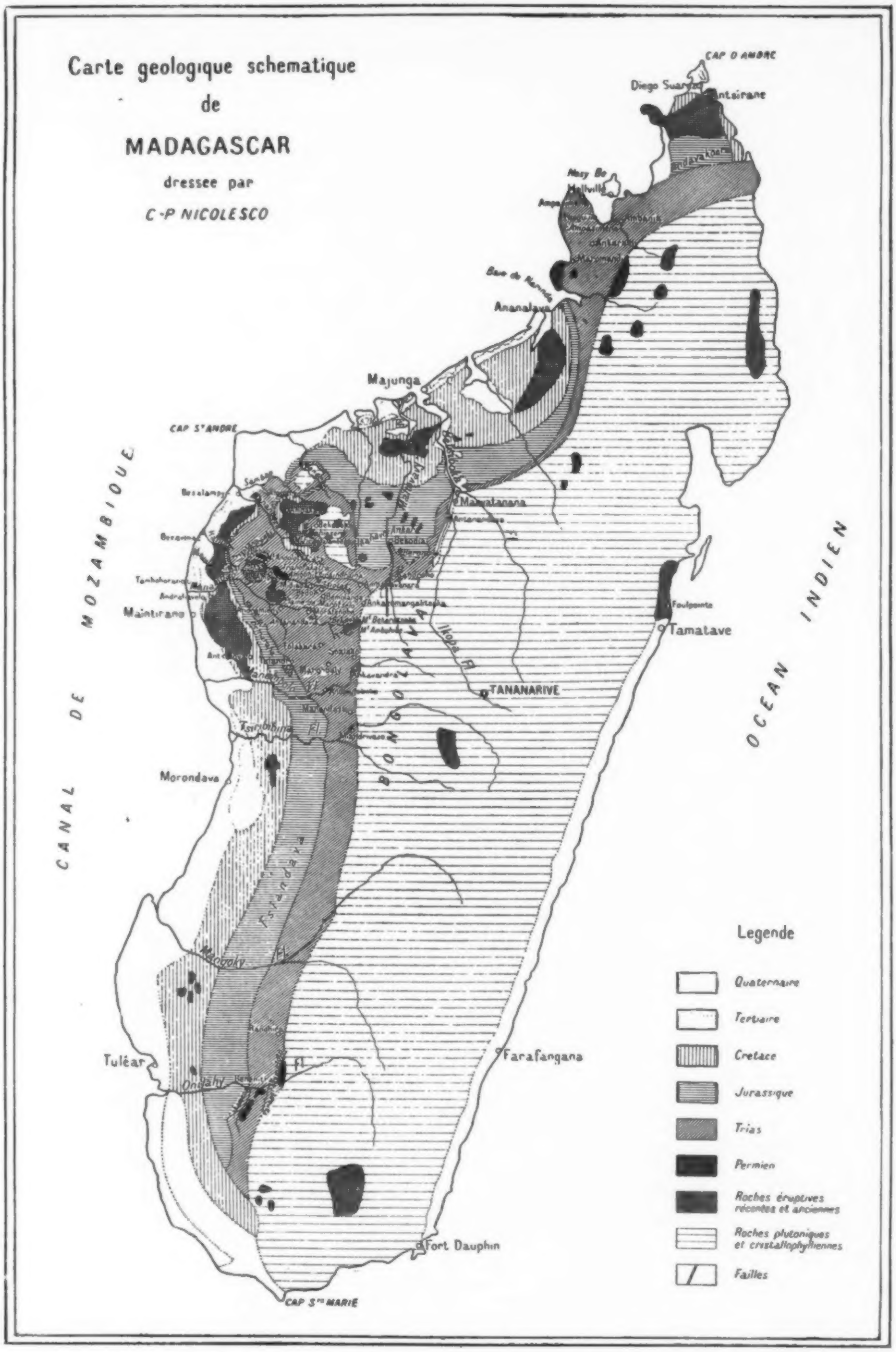

FIG. 1.—Geologic map of Madagascar. North-south length, approximately 930 miles. From C. P. Nicolesco's "Gisements pétrolifères de Madagascar," *La Revue Pétrolifère* (Paris), No. 388 (September 6, 1930), pp. 1228-29.

distillation and upward migration from the underlying Permo-Carboniferous rocks.

The age of the reservoir rocks is principally Permo-Triassic and Triassic; the age of the source rock is upper Permian; and the age of the accumulation of petroleum seems to be either middle Cretaceous or upper Miocene.

The petroliferous formations of Madagascar probably contain commercial deposits. To open them it is necessary to: (1) survey the interior in detail, (2) study the outcrops of the petroliferous formations, and (3) survey the anticlinal structures of the potential belt.

The author is definitely of the opinion that the oil reserves of Madagascar are of great importance, and that they are of immediate commercial value. The delay in the recognition of the potentialities of Madagascar has been due entirely, according to the author, to too much theorizing and to too little actual detailed work by the earlier expeditions.

BASIL B. ZAVOICO

TULSA, OKLAHOMA
November 20, 1930

"The Devonian Rocks of Kentucky." By THOMAS EDMUND SAVAGE *et al.* *Kentucky Geol. Survey*, Ser. VI, Vol. 33 (Frankfort, 1930). 161 pp., 95 photographs, 2 maps, and 3 plates. Cloth.

Savage describes the areal distribution, the lithologic character, the columnar succession, the fossils, the unconformities, and the folding of Devonian rocks cropping out in 29 Kentucky counties and in the Pine Mountain territory. The introduction is a stratigraphic summary of the Devonian in Kentucky. A brief regional description of the Devonian system in the contiguous outcrop areas of Ohio, Indiana, and Tennessee, including correlation charts, would have completed an otherwise satisfactory presentation of the Devonian rocks in Kentucky.

Devonian rocks are brought to the surface in parts of central Kentucky by the Cincinnati arch. They are found on the east, south, and west flanks of the Jessamine dome. They also occur in the Cumberland Saddle province of south-central Kentucky, between the Jessamine dome of north-central Kentucky and the Nashville dome of central Tennessee.

The stratigraphic succession and the lithologic character of the Devonian system are not constant throughout the state. Representatives of the upper and middle divisions of the Devonian section of New York state are present at the outcrops. Additional members enter the underground section in the eastern Kentucky coal basin. The upper division in Kentucky contains no strictly diagnostic fossils, shows no evidence of hiatus, and seems to represent a continuous succession of deposition during some part of Senecan (Genesee-Tully) time. This division includes the widespread New Albany shales, and a basal sandy, dolomitic layer, the Duffin. The New Albany section consists of hard and richly bituminous black shales, ranging in thickness on the outcrop from 25 to 300 feet. The section has its maximum thickness (300 feet) in northeast localities on the east flank of the Jessamine dome; it is thinner on

the west flank of the Cincinnati arch than on the east flank; and in few places is it more than 35 feet thick in the Cumberland Saddle exposures. This upper division normally rests unconformably on the Boyle limestone of the middle Devonian division (Erian-Hamilton), but has been found in direct contact with Silurian and Ordovician strata. The middle Devonian division of the outcropping Kentucky section consists chiefly of limestones, correlatives of the Erian-Hamilton and the Ulsterian-Onondaga. The maximum combined section does not exceed 50 feet on the outcrop. Members of the middle Devonian division in Kentucky are designated as the Jeffersonville, Sellersburg, Silver Creek, Beechwood, Casey, and Boyle limestones.

Underground conditions of the Devonian system are not considered in this volume. Shales of the New Albany section afford important supplies of natural gas in parts of the east Kentucky coal basin; in fact, they have revived the natural gas industry in that territory. The shale gas development centers about an area of approximately 40,000 acres in Boyd County, and a potential area of 960,000 contiguous acres in parts of Lawrence, Martin, Johnson, Floyd, Pike, Breathitt, Knott, Perry, Letcher, and Leslie counties. Areas of commercial natural gas production seem to be confined to the territory where the New Albany shales exceed 400 feet in thickness; under cover in extreme southeastern parts of the state, the New Albany shales have a thickness of at least 1,200 feet. Virgin rock pressures are normal; initial open-flow volumes are commonly less than 500,000 cubic feet, but there have been wells having open-flow volumes as great as 3,000,000 cubic feet; the wells sweat, but do not yield free water; drainage and accompanying reservoir-pressure decline may be effective for a distance of ½ mile, perhaps farther.

Pages 163-257 are devoted to "The Midland Trail in Kentucky"[1] by Armin Kohl Lobeck. This is a physiographic and geologic guide book to U. S. Highway No. 60, illustrated with maps, diagrams, and photographs. Highway No. 60 traverses the northern parts of the state of Kentucky for 525 miles. It extends westward from Catlettsburg by way of Ashland, Lexington, Louisville, Henderson, and Paducah, to Cairo, Illinois. The route traverses every physiographic province of the state. Historical associations along the route are described. It is a timely contribution to a much needed series of guide books for the annual migrations of American automobile tourists.

HENRY A. LEY

TULSA, OKLAHOMA
November 16, 1930

"Natural Gas Sands of Eastern Kentucky." By W. R. JILLSON. *Kentucky Geol. Survey*, Ser. VI (Frankfort, 1930). A chart. Size, 25 × 30 inches.

Representative logs of sixteen gas fields in eastern Kentucky were selected. These logs were plotted on standard log forms by use of a color legend for ten types of rock penetrated by the drill. The chart assembly commences with the New Albany shale-gas field of Boyd County in the northeastern part of Ken-

[1]Reprint of *Kentucky Geol. Survey*, Ser. VI, Pamphlet 22.

tucky and extends southwestward to the Williamsburg gas field of Whitley County, a short distance north of the Kentucky-Tennessee boundary.

The chart is a subsurface correlation sheet showing the limits of the geologic systems involved. The position of formations and the range of the systems are indicated on the left of each log; the position of the natural gas "pays" on the right. The chart clearly shows the differences in thickness of the underground formations in eastern Kentucky.

There are ten natural-gas objectives in eastern Kentucky, namely, the Salt sands, Maxon, Big lime, Keener, Big Injun, Weir, Berea, Brown shales, Corniferous, and Big Six. All yield sweet gas except parts of the Corniferous. The first objective occurs in the Pottsville group near the base of the Pennsylvanian system; the next six occur irregularly through the Mississippian system; the eighth and ninth objectives are in the Devonian; and the Big Six is in the Silurian. Natural gas has been encountered in Ordovician limestones, but not extensively at this time. Accumulation is irregular in all objectives except the Brown shales. Lithology is an important factor in accumulation; structure is generally a minor factor. This chart should find wide distribution among operators in eastern Kentucky. It should be in the files of all geologists specializing in natural gas.

HENRY A. LEY

TULSA, OKLAHOMA
November 15, 1930

Methods in Geological Surveying. By EDWARD GREENLY and HOWEL WILLIAMS. (Thomas Murby and Company, 1 Fleet Lane, London, E. C. 4, England; D. Van Nostrand Company, 250 Fourth Avenue, New York, New York, 1930.) 420 pp., 81 figs., 3 pls. Price, 17 s. 6 d.

During the last two decades, the rapid increase in the use of geological surveying by those engaged in exploiting natural resources has caused a decrease in the interest in official surveying. This condition seems now to be changing as a result of the increase in the number of students graduating from our universities who have specialized in the various branches of geology. At present there is a considerable increase in the number of men who are planning to do official surveying. Such students will find this publication on *Methods in Geological Surveying* interesting and valuable. To a less extent those now engaged in geological work and those planning to enter private practice will benefit by study of the different methods outlined by these authors.

The volume is very comprehensive and, in addition to outlining methods used by leading geologists and official geological surveys, it contains an interesting summary of the historical development of maps and map-making. Another feature of the publication which will be of considerable interest to those who expect to engage in some special line of geological work is the comprehensive bibliography, which includes the best and most representative publications on the different subjects discussed in the book. The historical part occupies approximately one-fifth of the entire volume and treats the subject of representing areas by maps from its earliest development to the present time.

In discussing the subject of geological surveying, the authors give careful consideration to the instruments used in geological and topographical mapping. The authors' ideas concerning the relative values of barometers and the Paulin precision altimeter seem questionable, but most of the descriptions of the instruments and the discussions of their uses are excellent. The details of map-making from the making of field notes to the final construction of maps are very comprehensive and satisfactory. The chapter of most interest to petroleum geologists is "Calculation of the Thickness and Depth of Beds; Structure-Contour Maps, Isopachytes, and Geological Sections." Under this heading is included the discussion of methods of showing structures by means of geological sections and contour maps.

The publication is illustrated with excellent figures and plates, many of them taken from official publications, and each being used to illustrate a definite principle or method.

George C. Matson

Tulsa, Oklahoma
November 19, 1930

"Étude synthétique sur le Mésozoique mexicain." By Carl Burckhardt. *Mémoires de la Société Paleontologique Suisse*, Vols. 49-50 (Emile Birkhaeuser & Cie, Bâle, Switzerland, 1930). 280 pp., 18 tables, and 65 figs.

The veteran paleontologist and stratigrapher, Carl Burckhardt, to whom we are indebted for most of the pioneer geologic work on the Mesozoic of Argentina and Mexico, has in this latest volume compiled very nearly all that is known to date on the Mexican Mesozoic. The work is a veritable storehouse of information, almost encyclopedic in its scope. The author discusses comprehensively the basement and other rocks upon which the basal Mesozoic strata rest, the paleogeography of the different Mesozoic stages, the stratigraphy, the paleontology, much of the structure, and the affinities of the faunas with those of other parts of the world.

The reviewer has been unable to detect more than a single important error. The statement is made on page 85 that the upper Jurassic is probably lacking at Mezquital in the valley of the Rio Blanco, on the trail between Aramberri and Las Virgenes, in southern Nuevo Leon near the Tamaulipas border. However, Lyman C. Reed, E. R. Silliman, Walt M. Small, and the reviewer found 100 meters of fossiliferous Kimmeridge and Portland overlying the red beds and gypsum on the northwest flank of the Mezquital anticline. Both the lithology and the faunal content of these strata are the same as in the surrounding region.

Burckhardt's "Synthetic Study" is positively indispensable to any geologist who works in Mexico. The author is to be very heartily congratulated on his success in making such an extremely important contribution to geologic and paleontologic science. It demonstrates a clarity in judgment and a wealth of experience unfortunately attained by too few geologists.

Charles Laurence Baker

Houston, Texas
November 19, 1930

Angewandte Geophysik (Applied Geophysics). By G. ANGENHEISTER. *Wien und Harms Handbuch der Experimentalphysik*, Band 25, *Geophysik*, 3 Teil, *Angewandte Geophysik*. (Akademische Verlagsgesellschaft, Leipzig, 1930.) 556 pp., 253 text figures, maps, and illustrations.

The handbook comprises the following chapters.

"The Geological Basis of Applied Geophysics," by H. Reich. This chapter gives the physical properties of geologic bodies, specific gravity, elastic properties, magnetic properties, et cetera. Pages 1-46.

"The Gravimetric Methods of Applied Geophysics," by Karl Jung. This chapter presents the theory of the torsion balance, description of the instruments, theory of the measurements, and interpretation of the measurements. Pages 47-208.

"Air and Earth Seismology": O. Meisser, air seismology; H. Martin, instruments and methods of earth seismology, and seismic investigation of the earth. Pages 209-305.

"The Magnetic Methods of Applied Geophysics," by H. Haalck. This includes local disturbance of the earth's magnetic field by the magnetism of rocks, theoretical relations between embedded masses and local magnetic anomalies, and execution and results of magnetic prospecting. Pages 306-96.

"The Electric Methods of Applied Geophysics": J. N. Hummel, theory of the electrical methods, fundamentals, direct-current methods, alternating-current methods, and radio-wave methods; W. Heine, practical application of the electric methods; J. N. Hummel, radio-activity method. Pages 400-535.

This handbook is ably written and well printed. The reviewer was especially interested in the chapter on his special field, work with the torsion balance. This is one of the best general articles on the method which has been written. In keeping with the series to which this handbook belongs, the physical-mathematical theory of applied geophysics is treated much more thoroughly than the practical and geological application of the methods, but the treatment of the subject is well balanced. The German seems reasonably simple. The subject of higher mathematics, of course, occupies much of the book, but the discussion as a whole is not oppressively mathematical. This book is an excellent text-book for the advanced student of applied geophysics and a reference book for the practicing geophysicist. It should be in the library of every specialist in applied geophysics who can read German.

DONALD C. BARTON

HOUSTON, TEXAS
November, 1930

RECENT PUBLICATIONS

CALIFORNIA

Map of Naval Petroleum Reserve No. 1 (Elk Hills oil field). (U. S. Geol. Survey, Washington, D. C., 1930.) Scale, 1 inch = ½ mile; contour interval, 20 feet. Price, $0.10.

COLORADO

Map of State of Colorado. (U. S. Geol. Survey, Washington, D. C., 1930.) Scale, 1 inch = 8 miles. Price, $0.25.

"The Geology of the Golden Area, Colorado," by J. Harlan Johnson. *Colorado School of Mines Quarterly*, Vol. 25, No. 3 (Golden, Colorado, July, 1930). 33 pp., 13 figs. Bibliography. (Second edition, revised, of shorter paper published in 1925.)

GENERAL

"Flow of Oil Through Reservoir Rocks—A Summarization and Coördination of Available Information Concerning Factors Which Determine the Movement of Underground Fluids and Affect the Ultimate Recovery of Petroleum," by Byron B. Boatright. *Oil Bulletin* (Los Angeles, California, December, 1930), pp. 1277-79, 1336.

"Characteristics Which Determine the Value of Oil Zones," by George O. Suman. *Oil Weekly* (Houston, Texas, December 12, 1930), pp. 39, 42, 44, 46, 4 figs.

Stabilization of the Petroleum Industry, by Leonard M. Logan, Jr. (Univ. of Oklahoma Press, Norman, 1930.) Full of information that is enlightening and non-prejudiced. 248 pp., including appendix and index. Price, $2.50.

"The Coal Fields of the United States": "General Introduction," by M. R. Campbell; "Ohio," by J. A. Bownocker. *U. S. Geol. Survey Prof. Paper 100* (Supt. Documents, Washington, D. C.). 101 pp., 9 pls., 49 figs. Price, $0.70.

GEOPHYSICS

"Geodetic Operations in the United States, January 1, 1927, to December 31, 1929." *U.S. Coast and Geodetic Survey Spec. Pub. 166* (Washington, D. C., 1930). Free.

"Geodetic Survey in 1929." *Serial 482* (Supt. Documents, Washington, D. C.). Price, $0.10.

"Results of Magnetic Observations Made by the United States Coast and Geodetic Survey in 1929." *Serial 482* (Supt. Documents, Washington, D. C., 1930). Price, $0.10.

NOVA SCOTIA

"Drilling in Nova Scotia." *U. S. Bureau of Foreign and Domestic Commerce Foreign Trade Notes* (*Petroleum 314*) (Washington, D. C., December 1, 1930). Contains report of encouraging results in oil drilling operations at West Branch River, John Pictou County.

OKLAHOMA

"Geology and Petrology of the Wichita Mountains," by Malvin G. Hoffman. *Oklahoma Geol. Survey Bull. 52* (Norman, Oklahoma, October, 1930). 83 pp., 4 figs., 2 pls. Price, $0.57.

"Micropaleontology of the Wetumka, Wewoka, and Holdenville Formations," by Aldred S. Warthin, Jr. *Oklahoma Geol. Survey Bull. 53* (Norman, Oklahoma, October, 1930). 95 pp., 7 pls., 1 chart. Price, $0.57.

PERSIA

"Petroleum Notes." *U. S. Bureau of Foreign and Domestic Commerce Foreign Trade Notes (Petroleum 314)* (Washington, D. C., December 1, 1930). Contains report of discovery of oil deposits in the district between Kermanshah and Khaniquin.

SOUTH AMERICA

Handbuch der Klimatologie, Band II, Teil G: *Klimakunde von Südamarika*, by K. Knoch. (Gebrüder Borntraeger, Schöneberger Ufer 12a, Berlin, W. 35, Germany, 1930.) 349 pp., 34 maps, 7 diagrams. Price, 67 RM. 50 Pfg.

TURKEY

"Erdölvorkommen an den Ausflüssen des Euphrat," by Gr. Petunnikov. *Petrol. Zeits.* (Berlin, November 5, 1930), pp. 1107-9, 6 illus.

Petrol, by Kemal Lokman. (Ankara, Turkey, 1930.) A pamphlet on petroleum in which the author suggests a decided probability that Turkey may contain oil in commercial quantities as a prolongation of Iraq. 69 pp.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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PACIFIC SECTION ANNUAL MEETING, NOVEMBER, 1930

The Pacific Section of the Association held its seventh annual meeting at the Biltmore Hotel, Los Angeles, California, November 6 and 7, 1930. M. G. Edwards was chairman of the program committee. A concurrent meeting of the Pacific Section of the Division of Paleontology and Mineralogy was held at the Engineers Club. Outgoing officers of the section are R. D. Reed, president, and H. K. Armstrong, secretary-treasurer. Officers elected for the new year are: M. G. Edwards, president, Shell Oil Company, Los Angeles, and L. N. Waterfall, secretary-treasurer, Union Oil Company of California, Los Angeles.

The following papers were presented on the program of the section.

"The Geological Column of Western Washington," by GEORGE A. MACREADY
"Collophane from Miocene Brown Shales of California," by E. W. GALLIHER
"Type Localities of Tertiary Formations of California," by H. G. SCHENCK
"Progress of Geologic Branch, California State Division of Mines," by OLAF P. JENKINS

"The San Joaquin Clay of the California Pliocene," by W. F. BARBAT and JOHN GALLOWAY

"Truncation of Maricopa Sandstone Members at the Etchegoin-Maricopa Contact, Maricopa Flat," by E. R. ATWILL

"Additional Notes on the Stratigraphy of the Santa Ynez Mountains," by L. M. CLARK

"The Miocene Stratigraphy and Source Sediments for Vaqueros Oil, Santa Barbara District," by THOMAS L. BAILEY

"Petrography of Oil Shale," by R. D. REED

"The Problem of the Origin of the Oil Occurring in the Southeastern Portion of San Joaquin Valley," by A. R. MAY

"The Bacterial Genesis of Hydrocarbons from Fatty Acids," by LEWIS A. THAYER

"Stratigraphic and Economic Significance of the Kreyenhagen Shale of California," by OLAF P. JENKINS

"Considerations of the Possible Origin of Crude Oil in the Venice Field," by H. W. HOOTS and A. L. BLOUNT

"Effects of Underground Storage Conditions on the Characteristics of Petroleum," by PAUL W. PRUTZMAN

"Origin of Roumanian Oil," by E. K. SOPER

The following papers were presented by the paleontologists.

"Progress Report of Committee on Nomenclature," by GEORGE DOANE

"Foraminiferal Zoning in the Monterey Shale, Vicinity of Type Locality," by E. W. GALLIHER

"Use of Diatoms in Stratigraphy," by K. E. LOHMAN

SAN ANTONIO TECHNICAL PROGRAM, MARCH 19-21, 1931

The following preliminary list of papers will be included in the technical program of the Sixteenth Annual Meeting of the Association at San Antonio, Texas, March 19-21, 1931. Frederic H. Lahee, Box 2880, Dallas, Texas, is general chairman of the technical program committee. Members planning papers should submit titles and abstracts before February 20, for inclusion in the printed program. As no preprints will be made this year, authors are requested to submit three carbon copies of their manuscripts with the first copy in order to facilitate discussion in advance of the meeting. Manuscripts should be in Dr. Lahee's hands by February 15.

PRELIMINARY LIST OF PAPERS

Texas and Mexico

"Reef Barriers and Saline Residues in Permian of Texas and New Mexico," by E. Russell Lloyd

"General Geology of Northeastern Mexico," by James L. Tatum

"Kingsville Field, Kleburg County, Texas," by Olin G. Bell

"Geology of Texas Panhandle," by H. E. Crum

"Early Paleozoic Seas in Texas Region," by E. H. Sellards

Source Beds and Origin of Oil

"Cretaceous Limestone as Petroleum Source Rocks in Northwestern Venezuela," by Hollis D. Hedberg

"Source of Oil in Venice Field, Los Angeles County, California," by H. W. Hoots

"Deposition of Source Beds," by Parker D. Trask

"Chemical Evidence on Theories of Petroleum Origin," by Benjamin T. Brooks

Oil-Field Waters

"Oil-Field Waters of Appalachian Region," by Paul D. Torrey

"Exceptional Relation of Oil and Water in Producing Zones at Refugio, Texas," by R. G. Maxwell

"Oil-Field Waters in Mid-Continent District," by L. C. Case

Geophysics

"Belle Isle Salt Dome: A Quantitative Study with the Torsion Balance," by Donald C. Barton

"Reflection Shooting in Mid-Continent," by E. McDermott

"Geothermal Variations in Coalinga-Kettleman Hills Area, California," by A. J. Carlson

Miscellaneous

"Further Data on Cap-Rock Petrography," by L. S. Brown

"Relation of Geosynclinal Basins to Development of Petroleum Provinces," by Raymond C. Moore

"Tioga County Gas Field in Northern Pennsylvania," by Jack Gaddess

"Mississippian Formation in Indiana, Illinois, and Kentucky," by J. Marvin Weller

"Physical Characteristics of Bradford and Other Typical Oil Sands of Pennsylvania and Their Relation to Production of Oil," by Charles R. Fettke

"Present Status of Carbon-Ratio Theory," by W. T. Thom, Jr.

"Mount Pleasant Pool, Leaton Pool, and Vernon Township Pool, Michigan," by George W. Pirtle and W. A. Thomas

"Age and Structural Relationship of Areas Adjacent to Southeastern Colorado with Buried Mountains of Texas Panhandle," by H. T. Morley

"Variation of Gravity of Oil," by Donald C. Barton

"Petroleum Possibilities of Turkey," by Djevad Eyoub

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Memorial

CASSIUS ASA FISHER

Cassius Asa Fisher died at his home in Denver, Colorado, on November 4, 1930, of angina pectoris, after an illness of several weeks. It is difficult to believe that so vigorous and forceful a man has ceased to live.

Fisher's life epitomizes the romance of oil geology during the past quarter of a century. He was born in Fremont, Nebraska, in 1872, attended public school and Fremont Normal School, and received his A. B. and A. M. in geology from the University of Nebraska in 1900. Later, in 1902, he did some graduate work at Yale.

Beginning in 1896, he did field work for the United States Geological Survey, and after graduating from the University of Nebraska he became a full-time member of the Survey staff. He was one of N. H. Darton's assistants in Darton's remarkable series of reconnaissance surveys in the West, and he later carried on similar work independently. Perhaps his best known work at this stage is his report on the geology and water resources of the Big Horn Basin, Wyoming.

With the development of the conservation movement, Fisher was drawn into the coal classification work that yielded such rich results in knowledge of the Cretaceous and Eocene formations of the Great Plains and Rocky Mountains. He had charge of a group of parties and later became assistant chief of the Fuel Section and a member of the Coal Land Classification Board. In the latter capacity he collaborated with Veatch and Ashley in promulgating the method of coal land classification and valuation which forms the basis of the method still in use.

The Fuel Section's stratigraphic work led inevitably to oil geology, which the oil industry was beginning to recognize. Ralph Arnold left the Survey to engage in consulting work in California, and in 1909 Fisher resigned to enter partnership with Arnold, opening an office for the firm in Denver. One of his earliest jobs was a study of Salt Creek, where the first two Wall Creek wells had recently been brought in. Midwest Oil and associated companies were struggling valiantly to keep alive, and Fisher's enthusiastic report was a major factor in securing the financing they so desperately needed. He took most of his pay in stock and thus passed, in hardly more than a single stride, from a modest Government salary to affluence.

His Salt Creek work and his subsequent work for the Midwest group made him what he remained until his death, one of the best known oil geologists in the Rocky Mountain region. During these years the firm of Arnold and Fisher was dissolved and was succeeded, after a time, by the firm of Fisher and Lowrie, the new member of the firm being Harold W. Lowrie, Jr. The succeeding years were full of expanding activity, in which Fisher not only did geologic work in the United States, Latin America, and Europe, but also sponsored

CASSIUS ASA FISHER

many oil-development enterprises. Among its other activities the firm became one of the leading authorities on taxation and valuation of oil properties. During the past year Fisher was engaged in enterprises of major scope from Canada to West Texas.

Fisher was among the pioneers in the application of geologic ability to the oil industry and in demonstrating the business value of technical work. His career was an exposition of the fact that business ability and scientific skill are mutually advantageous.

Aside from his ability as a geologist, Fisher's chief assets were his enthusiasm and his personality. He had the gift of making others see his visions. Wherever he went he made friends and kept them. He leaves Mrs. Fisher, his comrade since college days; a daughter, Mrs. Eleanore Fisher Leys, rapidly gaining recognition as a sculptress; and two sons, Maurice H. and Robert.

His unexpected death in the full vigor of accomplishment terminates an unusual life of geologic achievement, business success, and domestic happiness.

MAX W. BALL

DENVER, COLORADO
November, 1930

GEORGE STEINER

George Steiner was born in Arad, Hungary (now Roumania) on May 26, 1895, and was a young boy when Baron Eötvös was making his famous Arad survey with the torsion balance. He entered Wismar Polytechnic Institute, Germany, in 1912, and obtained the degree of mechanical engineer in 1919. He spent the years 1915 and 1916 with the Hungarian Gas Company, drilling for gas in Transylvania, and the years of 1917 and 1918 in the Hungarian army as lieutenant of engineers. During 1920 and 1921, he attended the University of Toulouse, France, receiving the degree of doctor in geology with honorable mention. In 1922 he was field chief of exploitation at Moreni, Roumania, for the Petrol Block.

Dr. Steiner emigrated to the United States and started to work in petroleum engineering in Texas, but, realizing the coming importance of the torsion balance in this country and the possibilities for the sale of the instruments, he returned to Hungary and obtained the American agency for the original Eötvös torsion balance. He returned to this country and became a very patriotic, naturalized American citizen. Until his death he engaged in consulting torsion-balance work and sale of the instruments, with offices in Houston, Texas.

In 1925, on a trip to Budapest, he married Miss Klari Zimmerman.

Dr. Steiner became an associate member of The American Association of Petroleum Geologists in April, 1924, and was transferred to active membership in December, 1926. In addition to his doctor's thesis on "The Natural Gas of Transylvania," he wrote "Torsion-Balance Principles as Applied by the Original Eötvös Torsion Balance," published in this *Bulletin*, Vol. 10, No. 12 (December, 1926), pp. 1210-26.

Dr. Steiner was killed at Spurger, Texas, on October 8, 1930, on a trip of inspection to one of his field parties, when his plane crashed on the take-off.

DONALD C. BARTON

HOUSTON, TEXAS
December, 1930

HENRY JESSUP PACKARD

Henry Jessup Packard died the morning of October 18, 1930, from acute peritonitis, which followed an emergency operation for a gangrenous appendix performed October 12.

Mr. Packard was born in Palmyra, New York, in 1883. His family moved to California while he was young and he received his education in that state. He graduated from Stanford University in 1911 with the degree of A. B. in geology and mining. After graduation he worked as metallurgist and geologist with various mining companies until 1920. In this period he spent one term with the Caribbean Petroleum Company in Venezuela, and was for two years geologist on the Hetch Hetchy aqueduct project of the City of San Francisco. In 1920 he came to the Rocky Mountains and joined the staff of Harrison and Eaton, consulting geologists of Denver. He was in Montana in 1920 for The Midwest Refining Company interests and until 1924 was staff geologist for T. S. Harrison. In 1924 he joined the Mutual Oil Company as chief geologist. The Mutual later merged with the Continental Oil Company and the Continental, in turn, with the Marland. Packard retained his position through these changes and was serving at the time of his death as assistant chief geologist, with headquarters in Denver.

Packard was elected to membership in The American Association of Petroleum Geologists in 1925. He had long been a member of the American Institute of Mining and Metallurgical Engineers.

Those of us who were privileged to know Packard were impressed, first, with his quiet and unobtrusive manner, beneath which was a keen and inquiring mind. He was a student of all phases of the oil industry, although his chief activity was in geology. He was slow to make up his mind about a man or a prospect but, having done so, his conclusions were well founded. He was essentially of a kindly nature and in an acquaintanceship of years was never known to make a disparaging remark about a fellow man.

Mr. Packard is survived by his wife, Johnnie K. Packard, and daughter, Mary Louise.

H. A. STEWART

DENVER, COLORADO
November, 1930

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

Employment

The Association maintains an employment service at headquarters under the supervision of the business manager.

This service is available to members who desire new positions and to companies and others who desire Association members as employees. All requests and information are handled confidentially and gratuitously.

To make this service of maximum value it is essential that members coöperate fully with headquarters especially concerning positions available to active and associate members.

Hugo Böckh has been appointed director of the Hungarian Royal Geological Survey, with the rank of under-secretary of state. On the basis of torsion-balance work in Transylvania, Dr. Böckh was the first to show the value of the torsion balance in mapping salt domes. He has worked for the Anglo-Persian Oil Company in Persia and elsewhere.

Fred J. Funk is geologist for The Ohio Oil Company at Casper, Wyoming.

C. Max Bauer, R. 3, Box 116, Boulder, Colorado, addressed the Rocky Mountain Association of Petroleum Geologists, November 20, 1930, on "Red Beds,—A Discussion."

Fred P. Shayes, formerly geologist for the Houston Oil Company, is now geologist for the South Texas division of the United Gas Corporation, with headquarters at Beeville.

Raymond H. Haseltine, of the Sun Oil Company, Dallas, Texas, is in charge of diamond-drilling work for the geological department in Texas.

Roy A. Payne is geologist for the Gulf Production Company at 735 Milam Building, San Antonio, Texas.

K. C. Heald, staff geologist for The Gulf Companies, Pittsburgh, Pennsylvania, has been elected a fellow of the Royal Geographic Society, London.

T. E. Swigart, superintendent of production, Shell Oil Company, Los Angeles, California, presented a paper on "Economic Problems of Unitization," before the Chicago meeting of the A. P. I., in November. The paper is published in the November 20 issue of *The Oil and Gas Journal*, and in the November 21 and 28 issues of *The Oil Weekly*.

H. de Cizancourt has returned to Paris after a trip of five months in western Madagascar. Mrs. de Cizancourt accompanied him.

F. H. LAHEE, third vice-president, in charge of editorial work, attended the annual fall meeting of the Pacific Section of the Association held at Los Angeles, November 6-7, 1930.

J. J. GALLOWAY, of Columbia University, New York, New York, addressed the Tulsa Geological Society, December 1, 1930, on "Some Relations Between Diastrophism and Stratigraphy."

A. C. TROWBRIDGE, professor of sedimentology, University of Iowa, Iowa City, and director of the government dam survey along Mississippi River, delivered the principal address, November 28, at the nineteenth annual meeting of the Oklahoma Academy of Science, Tulsa, Oklahoma, November 28 and 29. His subject was "A Search for Dam Sites on the Upper Mississippi River."

The West Texas Geological Society held a regular meeting November 22, at Midland, Texas. H. P. BYBEE and C. P. BUTCHER, both of San Angelo, gave a paper on "General Geological Features of West Texas and Southeast New Mexico," and Mr. Butcher gave a paper on "Notes on the Gas Reserves of Southeast New Mexico."

A. A. HAMMER is connected with the Minnesota Northern Power Company. His address is 2526 First Avenue North, Great Falls, Montana.

HARRY L. BALDWIN, Jr., formerly district geologist for the Independent Oil and Gas Company at Oklahoma City, is now with WILLIAM H. ATKINSON, 701 Continental Building, Oklahoma City, Oklahoma.

FREDERICK G. CLAPP, consulting geologist, 50 Church Street, New York, New York, spoke on the oil fields of Persia, before a meeting of the San Antonio Section of the Association, December 1.

BURR MCWHIRT, valuation engineer in the geological department of the Shell Petroleum Corporation, has been transferred from the Tulsa office to the office of the Gulf Coast division at Houston, Texas.

The North Texas Geological Society, Wichita Falls, Texas, has elected the following officers for the coming year: president, WILLIAM J. NOLTE, Dixie Oil Company; vice-president, H. F. SMILEY, Deep Oil Development Company; secretary-treasurer, VIRGIL PETTIGREW, Humble Oil and Refining Company.

A. BEEBY THOMPSON, petroleum engineer, 18 St. Swithins Lane, London, E. C. 4, England, was in Los Angeles on business in November.

H. M. E. SCHURMANN, chief geologist for the Bataafsche Petroleum Maatschappij, The Hague, Holland, attended the meeting of the American Petroleum Institute in Chicago last November, and also visited the oil fields of the Mid-Continent.

DJEVAD EYOUB, who is back in the United States after a year's stay in the Near East, where he examined the oil possibilities of the Turkish Republic for that government, plans to be occupied in northern Mexico until the spring, when he will return to Turkey. His address is 302 Furr Drive, San Antonio, Texas.

R. E. GILE, formerly with the Independent Oil and Gas Company, at Tulsa, Oklahoma, is now employed by the Superior Oil Company of California, at San Angelo, Texas.

F. W. LAKE has been promoted from production superintendent to general superintendent of the southern division of the Union Oil Company, at Santa Fe Springs, California.

NOEL EVANS, of Guthrie, Oklahoma, presented a paper on "Permian Stratigraphy of Northwestern Oklahoma," before a meeting of the Tulsa Geological Society on December 15, 1930.

Mining in California, the quarterly report of the state mineralogist, is now devoting a chapter to the activities of the Geologic Branch. OLAF P. JENKINS is chief geologist.

W. E. WRATHER, 4300 Overhill Drive, Dallas, Texas, presented an illustrated lecture on "A Trip Through the Alps" before the Dallas Petroleum Geologists, on December 19, 1930. The lecture dealt with some of the general geology and geography of Switzerland and Italy.

RICHARD E. KOCH, of the geological department of the Caribbean Petroleum Company, Maracaibo, Venezuela, left Maracaibo in January for a vacation to be spent chiefly in Switzerland. His address will be 9, Hegenheimerstrasse, Basel, Switzerland.

Recent speakers before the Geological Society of Northwestern University, Evanston, Illinois, and the titles of their addresses are: G. R. MANSFIELD, of the U. S. Geological Survey, "New Discoveries in Geologic Structure"; DAVID WHITE, U. S. National Museum and Geological Survey, "Stratigraphic Problems of the Permo-Carboniferous"; MARGARET FULLER BOOS, U. S. National Park Service, "Geology of the Bryce Canyon Region"; EARL A. TRAGER, Skelly Oil Company, Tulsa, Oklahoma, "Subsurface Correlation in the Mid-Continent Field"; G. F. LOUGLEN, U. S. Geological Survey, "What Is an Economic Geologist?"; DOUGLAS W. JOHNSON, Columbia University, New York City, "Significance of the Low Shore Terraces"; and KING HUMBERT, University of Chicago and Columbia University, "Isostasy."

T. S. HARRISON, formerly of Denver, Colorado, and JACK M. SICKLER have offices in the Pacific Mutual Building, Los Angeles, California.

J. H. NELIMARK is working for the Darby Oil Company in West Texas.

The Kansas Geological Society, Wichita, Kansas, met December 6 and elected the following officers for the ensuing year: president, WALTER W. LARSH; vice-president, EVERETT A. WYMAN, Amerada Petroleum Corporation; and secretary-treasurer, PAUL A. WHITNEY, Mid-Continent Petroleum Corporation.

The Tulsa Geological Society, at a regular January meeting, elected the following officers for the coming year: president, R. S. KNAPPEN, Gypsy Oil Company; first vice-president, F. A. BUSH, Sinclair Oil and Gas Company;

second vice-president, C. L. SEVERY, 816 Kennedy Building; secretary-treasurer, RONALD J. CULLEN, Twin State Oil Company; and a council consisting of HARRY F. WRIGHT, Box 1993, LUTHER E. KENNEDY, Douglas Oil Company, and H. E. ROTHROCK, Superior Oil Corporation.

The West Texas Geological Society held its regular monthly meeting on December 13, 1930, at San Angelo, Texas. JOHN EMERY ADAMS, of The California Company, Midland, presented a paper on "Anhydrite Inclusions in the Big Lime in the West Texas Permian Basin." The following officers were elected for 1931: president, R. L. CANNON, of Cannon and Cannon, San Angelo; vice-president, JOHN EMERY ADAMS; and secretary-treasurer, H. A. HEMPHILL, University of Texas Land Survey, San Angelo.

DONALD K. MACKAY, petroleum geologist, has returned to Pampa, Texas, from work in western Kansas. Mr. Mackay has offices at 305 Rose Building, Pampa.

NELSON T. POTTER is geologist for the Empire Gas and Fuel Company at Chickasha, Oklahoma.

ANDREW GILMOUR, geophysicist for the Geophysical Research Corporation, Tulsa, has recently returned from a visit to his former home in north Ireland.

WALTER C. MENDENHALL was appointed, December 22, 1930, acting director of the U. S. Geological Survey.

M. G. CHENEY, of Coleman, Texas, represented the Committee on Stratigraphic Nomenclature at the Toronto meeting of the Geological Society of America, in December.

M. C. ISRAELSKY, of Shreveport, Louisiana, is paleontologist for the United Production Corporation.

E. RUSSELL LLOYD has opened an office as consulting geologist in Midland, Texas.

A. I. LEVORSEN, formerly chief geologist of the Independent Oil and Gas Company, Tulsa, is now engaged in consulting work at Tulsa.

ROBERT J. RIGGS, chief geologist of the Indian Territory Illuminating Oil Company of Bartlesville, Oklahoma, was in Mexico on business last December.

B. H. HARLTON, micropaleontologist for the Amerada Petroleum Corporation, Tulsa, Oklahoma, is studying the origin of oölites, and would appreciate references and data on this subject.

E. A. STILLER, of the Arkansas Natural Gas Company, Shreveport, Louisiana, is head of the land department.

SAM H. WOODS, geologist for the Twin State Oil Company, has been transferred from Ardmore to Tulsa, Oklahoma.

J. ELMER THOMAS, of Fort Worth, Texas, returned from an extensive trip through Europe to spend Christmas at home.

SIDNEY POWERS, of the Amerada Petroleum Corporation, Tulsa, Oklahoma, was elected a councilor of the Geological Society of America, at the Toronto meeting of that society in December.

EUGENE STEBINGER, in charge of the geological work of the Standard Oil Company of New Jersey in Argentina, has returned to Buenos Aires after a trip through the United States with C. F. BOWEN, chief geologist, of New York City.

OLIVER B. HOPKINS, chief geologist of the Imperial Oil Company, of Toronto, Canada, is making his annual inspection trip of the properties of the International Petroleum Company in Colombia and Peru.

J. J. GALLOWAY, consulting micropaleontologist, has returned to Columbia University, New York City, after spending several months in Tulsa.

ROY A. REYNOLDS, consulting geologist of Fort Worth, Texas, will return in March from a professional trip to Europe.

D. F. ALLEN is doing consulting work at San Angelo, Texas.

E. DEGOLYER. 65 Broadway, New York, N. Y., presented a paper at the Toronto meeting of the Geological Society of America, in December, entitled "Geophysics, A New Tool for the Geologist."

L. V. A. FOWLE, geologist for the Iraq Petroleum Company, London, has been making an inspection tour of the oil fields of North America.

M. TAYLOR briefly describes the Grand Saline salt dome in an article entitled "Shaft Sinking at Texas Salt Mine" in *Mining and Metallurgy* for December, 1930. Shafts are now being sunk at Hockley salt dome, near Houston, Texas, and at Winnfield salt dome, near Winnfield, Louisiana.

GEORGE OTIS SMITH has been appointed chairman of the Federal Power Commission.

FRED P. SHAYES has resigned from the Houston Oil Company and is now division geologist for the United Production Corporation, with headquarters at Beeville, Texas.

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